Digitalization Meets Improvisation:

Developing a personal way of dealing with the rising digital presence in design

Nur Horsanalı
Master's Thesis

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Master's Thesis:
Submitted to the Department
of Design in Aalto University
for the degree of Master of Arts
in Product and Spatial Design
Program

Supervisor and Advisor:
Maarit Mäkelä

Thanks to:
Anna van der Lei
Signe-Anita Lindgre
Jasper Eikmeier

Helsinki, 2019

Abstract

As design and production practices are becoming more digitalized, designers are expected to adapt to the changing circumstances straight away. From the perspective of young designers who appreciate working hands-on, these changes may pose challenges and therefore finding ways to tackle them are needed. This thesis addresses the pointed out matter and arises from the effort of a young designer striving to position herself within the digitalization of the product design field. In this open-ended process where research, production, and personal experiences are intertwined, I enter into a self-dialog that enables me to question the ambiguous meaning of digitalization and my own standpoint. Through this, I acknowledge that it is needed to maintain an open but critical manner towards the changes in the field in order to perceive alternative approaches. Rather than fearing or ignoring digitalization, designers should find means of dealing with it.

In my case, handling digitalization becomes possible through exploring a new dialog between a designer and an unfamiliar digital machine, 3D clay printer. This computer-based yet imperfect medium presents an ideal ground to investigate the designer's position between digital and hands-on since the process involved both of these aspects. Along the way, as I recognize that the machine has an agency of its own, I accept it as my partner who I improvise along. Exploring improvisation as a tool for adapting to changing situations, embracing mistakes and spontaneity, leads me to overcome the unfamiliar process I enter.

Through this practice-led research, I explore how to be open towards digitalization and it becomes apparent that not every prejudice of mine was truthful. I discuss that the level and quality of approaching changes in design can be personal. For instance, in my empirical study, the bridge I find between digitalization and improvisation enables me to find a means of working hands-on within a digital process. This thesis highlights that developing a personal approach retaining the connection to the designer's own way of working is fundamental for dealing with the rising digital presence in design.

Keywords: *digitalization, improvisation, 3D printing, design exploration, practice-led research*

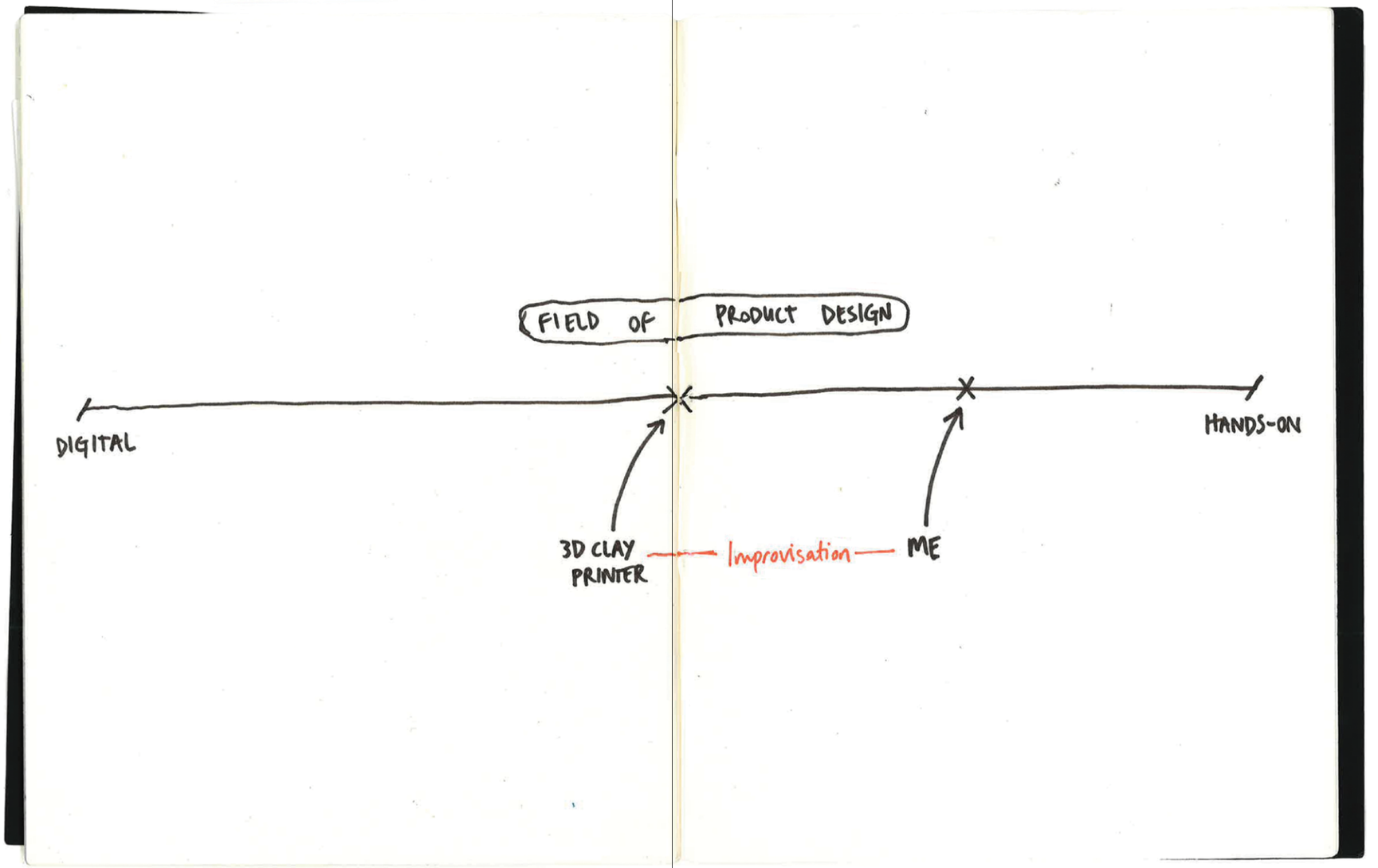

Figure 1. Diagram from my notebook visualizing the spectrum I imagine that represents my field where one end is digital and one end is hands-on.

Part 1:
Introduction

1.1. *Introduction*

As I was observing my classmates and colleagues, I realized their design practices were based on different sources of motivation. Some designers were motivated by emerging technologies and their applications in the design field and they were keen to learn how to use various digital tools and software. Contrarily, some designers were motivated and inspired by working with their hands and connecting to the physical material—which I refer as being hands-on throughout the thesis. I am imagining a spectrum that represents my field product design, where one end is digital and one end is hands-on, assuming that every designer has a position on this spectrum. Naturally, the designer's positioning between the two ends is in flux as the interest of designer in production mode may differ over time. At present, I have positioned myself somewhere closer to the hands-on side of this spectrum.

What has been happening in the contemporary situation is that positioning themselves between hands-on and digital is beyond the designer's preference. As the presence of digital is constantly rising in design and craft practices, surviving as a product designer working with hands becomes more challenging today. The practice and the role of the designer are considerably influenced in the realm of digitalization and it is expected from designers to adapt to the changing circumstances in the field (Verbruggen, 2014). This matter led me to question the differences between my individual identity and professional expectations (Kosonen, 2018). The questions I asked were: where was I standing, where was I expected to stand and how could I deal with the changes in my field due to digitalization.

While the profession of product design is shaping into systems and services (Muratovski, 2016), into "digital product design", I had the drive to investigate new approaches to keep my connection to the hands-on within digitalization. During the course of this thesis, instead of defining digitalization as a problem, I acknowledged the situation and entered into a self-dialog to investigate my relationship with it further. Through this, I aimed to investigate how I sense myself in a digitalized field—my own awareness and involvement in it (Dufva, 2018).

In order to address these issues, I needed to be open towards digitalization and get myself involved in a digital process. Eventually, working with a 3D clay printer has become the medium for my investigation. This machine consisting of both digital and hands-on aspects represented the middle ground between the two ends of the field; it represented a metaphor for rethinking the designer's position between hands-on and digital. In order to work with this digital machine, utilizing improvisation—an interest that I have previously developed

through my design practice—came to be meaningful. I found a cross-disciplinary connection between digitalization and improvisation that enabled me to explore a way to handle the unfamiliar process I have entered.

Bertinetto (2013b) and Gasson (2015) suggest that the practice of improvisation in the performing arts fields provide a means of handling unknown situations and adapting to changing circumstances. In addition to realizing that the elements in improvising were linking to the needed skills to deal with a rapidly changing society and discipline, I have also explored what it can mean for the creative process of a designer. Understanding improvisation can allow going beyond formalized routines, embracing mistakes, and seeing the creative potential of events occurring in the moment of production (Bertinetto, 2013b; Weick, 1998). Improvisation became a tool in my process to be spontaneous and flexible, to relinquish control—which directly affected the way I worked with the 3D printer.

How can one deal with the changes in their field while retaining the connection to their personal ways of working? Can one find a balance when positioning themselves between hands-on and digital? How can digitalization be addressed from the perspective of improvisation practice in the fields of performing arts? This thesis tackles with such questions discovered through my self-dialog as a young product designer. Entering into this dialog enabled me to understand my standpoint and prejudices, as well as the alternative perspectives (Denshire, 2013).

The thesis consists of both theoretical and practical explorations. Often times, the theory was intertwined with my past and present personal experiences. Theoretical parts discuss wider concepts such as digitalization and improvisation, and my relationship with both. These parts of the research aided to define values that I would further explore practically. The practical part of the thesis subjectively addressed the issues in question through making, reflecting and analyzing.

1.2. *Personal Background*

As I was re-analyzing my past experiences during this thesis, I have found new meanings in them. I could see that starting early on in my design education, I have always been in between crafts-based and digital-based aspects of design. Through this re-analyzing, I could also better understand how my connection to hands-on developed. During my bachelor's education in Turkey, where I was studying industrial product design, I did not have a very direct connection to

materials due to the limited workshop facilities. Even though the facilities at the university were limited, the local craftsmen doing small-scale production were still present in Istanbul outside the school context. It was possible to find all types of craftsmen working with their hands and with almost any material imaginable. Therefore, throughout my bachelor's studies, I often worked alongside craftsmen and learned the traditional aspects of crafts. These educational and social experiences shaped my understanding of what craft and craftsmanship means, and eventually influenced the value I give to the hands-on approach in design. On the other hand, even if we did not have material workshops at the university, we had access to various digital fabrication tools; and I have been around these as much as I have been around the craftsmen. I used the digital tools often, but to be honest, I have never felt that particular excitement I had while I was working and learning alongside the craftsmen.

After starting my master's studies in Finland, with the availability of many material workshops, my interest on learning crafts have continued, but my focus was shifted more on exploring materials on my own and through my hands. As the value that I attributed to hands-on production continuously increased, I have continued to dissociate myself from my background, industrial product design, to this day. Meantime, I have also realized that I no longer found designing products appealing, I rather found examining the ways of making and the behavior of designing more exciting. In the past years, I was almost not at all interested in the outcomes, rather the explorations and joy I was getting out of these processes were intriguing. Muratovski (2016) states that some designers want to focus on the process of "making" while others on the process of "thinking". As a designer, I became interested in "thinking about making".

If I recall, my interest in improvising also dates back to my bachelor's studies. I graduated from the industrial product design program with a research project that examined processes opposite from the planned, formalized, automated aspects of industrial design. This project examined the spontaneous and intuitive production practices occurring in everyday life in the context of Istanbul; how non-designers were responding to their problems using the means they had at hand without pre-planning. I believe that examining this topic—which also relates to the concepts of *bricolage* and *adhocism*—in my bachelor's thesis intrigued my interest in improvisational behavior. The unplanned, spontaneous and flexible processes and the practice of producing in a given setting were interesting to me starting from this point. Improvisation continued to get me thinking during the moments in my education in Finland as well. As my attention was drawn more into material exploration, I realized how my processes were also extemporaneous. The idea to investigate how this type of spontaneous creativity works was intriguing to me.

Approach to Research

My approach to design research has been developing through this master's thesis and I have been exploring the subjective ways to research. Muratovski (2016) argues that design research should define an exact problem, otherwise you cannot find a solution. This makes me think whether if research in design should always need to concerns "problems" and "solutions". My thesis did not aim to solve a problem; it was about exploration, making sense of something through personal experiences and self-dialog. To me, design research can also be about opening discussions, seeking new perspectives, and learning about yourself. By questioning the state of design and its processes, investigating different perspectives of other fields, we can understand ourselves as designers better.

Gaining a subjective experience of the subject I research was important as the main objective of my thesis was to understand where I was standing in the field. During the course of this thesis, I aimed to analyze and make sense of how my own design ideology evolved starting from my bachelor's education until the end of my master's education. Through my research, I wanted to comprehend my personal interests, prejudices, what drives me in a creative process and what do I problematize. The process of researching and writing also allowed me to understand and develop my academic self and to discover what methodological approaches are interesting to me.

Part 2:
Digitalization

2.1. *Digitalization of Product Design*

In the summer of 2016, I attended an international workshop held in Istanbul by the AA School of Architecture. While the end goal was to build a large-scaled vault structure, the workshop itself was highly focused on digital fabrication processes and computational design. The selected construction material, styrofoam blocks, were determined to be carved using a robotic arm with a hot-wire cutter attachment on. Being around this vast robotic machine and having to learn all the software for parametric modeling, coding, and controlling the machine was the most digital state I ever reached throughout my design education and, I have to admit, it was greatly overwhelming.

After a few days, the tutors decided that the robotic arm, which was the main attraction of this workshop, was too slow in cutting the styrofoam blocks and it was eventually delaying the upcoming building part. Due to this, the tutors formed a separate group to build an analog machine that will work alongside the robot and accelerate the production process. As I was already questioning why I was a part of such a digital-focused workshop, I happily joined this team and built an analog hot-wire cutter overnight using the scrap materials we found at school. It was quite a humorous situation for me to build this low-tech machine to support a robotic arm.

The role of the robotic arm was to cut the components —which would form the vault structure—and to carve rippled surfaces that were generated using computational design tools on these components. What we were interested in as we were building the analog machine was to obtain different forms of ripples and textures that could not have been possible to generate

using digital tools. We succeed in capturing unique waves and textural effects on the styrofoam material as a result of the imperfection of the machine. In the end, the components we produced using the analog machine formed one part of the vault structure alongside the components produced by the robot.

Digitalization has been rapidly entering into every aspect of our lives, and our surroundings are now in a blend of digital and physical (Fors, 2010). Dufva (2018) explains that individuals may have different "modes of being in the digital world" separately from their understanding of the technical aspects of digital technologies (p. 52). Some might not be aware or question the relationship between the physical and digital worlds whereas some might

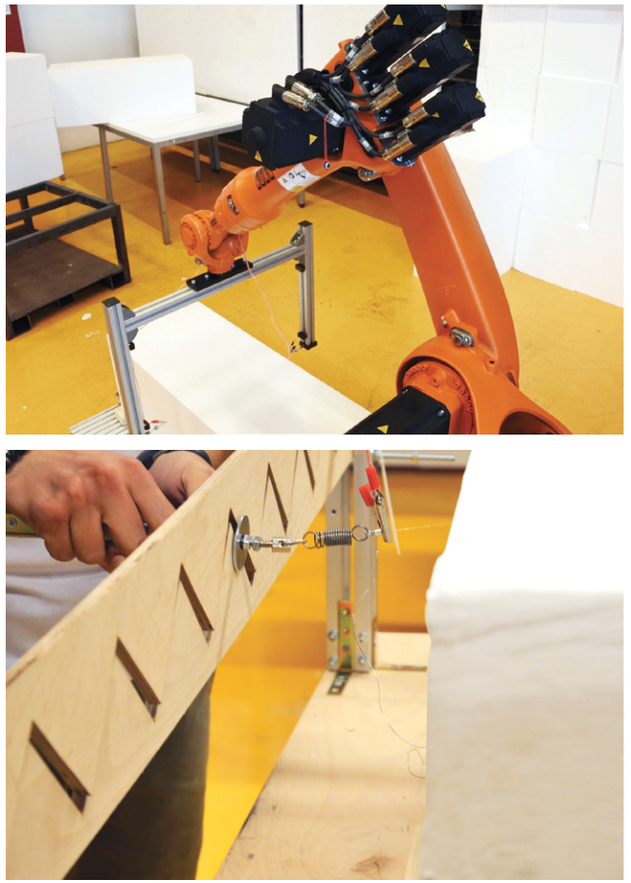

Figure 2. KUKA robotic arm with a hot-wire cutter attachment and the low-tech machine built to support the production process, during AA Istanbul Visiting School 2016.

problematize the distinction between these worlds and paying attention to who defines the modes of being in digitality. I certainly had an awareness of the separation of digital and physical, as well as hands-on and computer-based. At the same time, as a young product designer, I somehow had a complicated relationship with my field being digitalized.

3D printing, laser cutting, CNC manufacturing, robotic fabrication, virtual reality… As digitalization has been moving from one digital tool to another, I have continuously been around these concepts throughout my education. I have to admit, to a certain extent, I felt satisfied to be able to use these means—as if I was smarter that I understood something computerized. Even if I have developed the knowledge and skills to use these digital fabrication tools that were emerging in my field and I have never alienated myself from them, I was nevertheless negatively biased towards them. The point I questioned was that what all these tools meant and why designers were expected to embrace and utilize every new means emerging. During the course of this thesis, I was still trying to figure out what did the processes of design being digitalized meant.

Digitalization is defined as the process of transforming something previously physical or analog into universal digital forms (Digitalization, n.d.; Dufva, 2018). Fors (2010) argues that everything that is possible to digitize will be digitalized. Therefore, no matter what my personal feelings towards digitalization are, it cannot be ignored that it will continue to change our everyday surroundings as well as our field and education. Ultimately, I have never questioned deeper what aspects I found problematic about what is happening; it was somehow a default argument I had, "digitalization is bad".

So, what was it that I understood by this big word "digitalization"? Essentially what it meant was that the practice of design shifting more into digital platforms, production becoming more automated, and hence, the hands-on and material-based design processes losing their presence. Design practice becoming digital meant that the focus is on efficiency and quantity rather than meaning and quality. Due to this, the outcomes would be lacking a sense of context, an identity, or that certain "imperfection" which gives irregularity and distinctiveness (Sennett, 2008). I felt that my attitude against digitalization and my belief that objects would become "soulless and distant" were very similar to the ideas emerged during the Arts and Crafts Movement opposed to machinery and industry (Warnier, 2010).

According to sociologist Richard Sennett (2008), "the model embodied by a perfect machine suggests that the work can indeed be done flawlessly" (p. 101). The "perfect" digital machines are initially designated to provide rapidity and efficiency in the process. What was it that I found problematic about this?

In my view, understanding production solely as efficiency was problematical since in this case, the practice of design appears less creative. To me, a production process does not only consist of realizing plans but also experiencing the creative process in the making. When the digital machine repeats same actions over and over again, a particular certainty is introduced into the production and the sense of "unexpectedness" is missing (Fyhn & Søraa, 2017; Warnier, 2010). In a computerized process where things have to be pre-planned from the beginning, there would be no room for exploration within the moment of producing. This made me presume that digital tools are generating uniform results. When production is becoming digitalized, automated, and therefore globalized, designers become ones who mainly operate the production, conceive and develop standardized products as Manzini (2009) points out.

2.2. *Hands-on Design and Digital Tools*

While digitalization was spreading within my field, I was working with materials through my hands more than ever. During my master's studies in Finland, I have been learning many crafts and enjoying my haptic experiences with new materials: ceramics, glass, wood, textiles. At the same time, I was aware that this type of hands-on design practice is gradually disappearing, and I associated digitalization as one reason for this. As I was investigating my problematic relationship to digital, I wanted to find out why it is still important to work with hands beyond romanticizing it. I questioned what it provided me or what can be its value in the contemporary context.

The meaning of crafts and working hands-on are gaining a more complex meaning in the times we now live in (Keep, n.d.). Keep states that people will continue to work with their hands because of what they get out of the process itself; if the focus was in the outcome, everyone would agree that the use of digital tools would be more sensible. It is clear that "making by hand should not only be understood narrowly as a creation of artifacts but as an inquiry as well as a belonging to the surrounding world" (Dufva, 2018, p. 38). In other words, hands-on processes are worthwhile to deal with the material world, to connect with our surroundings and to comprehend ourselves. In the era of digitalization and automation, even if we would not apply it as our means of production, we need to be hands-on to maintain our personal well-being and creative development (Dufva, 2018; 2009; Sennett, 2004). I believe that working with hands may have more significance for the design process, beyond providing well-being. As Hansen and Falin (2016) point out, being hands-on provides an in-depth understanding of the material properties that are valuable for the design practice as the presence of digital rises.

The initial aspect that influenced my negative attitude towards the digital was that I positioned it as the opposite of hands-on. Hansen and Falin (2016) suggest that this is not only my attitude but shared by many people:

> There exists an attitude when comparing the processes of hand-making and computer-based practice that the digital realm is alienating our embodied experiences from the material world. There is a fear that the knowledge, or "knowing", that traditional craftsmen have from making could be lost if digitalization takes over. Digitalization is seen as creating a distance between humans and the physical world. (p. 117)

This attitude has been going on ever since the industrialization and the same discussion could be addressed as "crafts" and "machines". According to Keep (n.d) and Sushma (2017), the impression that hand-made being ideal while machine-made being lesser in value has its roots in the "romantic notions" of the Arts and Crafts Movement in the 19th century. I wanted to go beyond my romantic impressions of hands-on, and the skepticism I developed against digital because of this. The common argument I explored was that the emergence of digital tools expanded the areas of crafts, design, arts, and offered new opportunities to create something novel. Therefore, digitalization should not be attributed as a threat to the hands-on rather it should be simply seen as an addition to the skillset of a designer (Dufva, 2018; Fors, 2010; Hansen & Falin, 2016; Hong, 2018; Keep, n.d.).

Ceramics artist Jonathan Keep (n.d.) who is actively working with a 3D clay printer in his current processes explains that he considers himself as a traditionalist and he does not see digital tools as a threat but just a development. He believes that traditional crafts and digital technology co-exist. Keep also criticizes the notion that working digitally is less creative than working hands-on. He explains: "whether working digitally is any less 'creative' obviously comes down to personal interpretation of creativity. Personally by extending my box of tools I feel I can be more creative. It comes down to how you use your tools" (Keep, n.d.).

According to popular historian David McCullough (1996) working with digital tools is just as working with any other tool associated with traditional crafts. Hansen and Falin (2016) also explain that the crafts have always developed through new technologies; they give the intriguing example of "potter's wheel was at one point a new technology, but a thrown pot is today considered handmade" (p. 115). Furthermore, McCullough even argues that the modern maker who is using the current digital technologies can be seen as a craftsperson building on the inheritance of the Arts and Crafts Movement. Sushma (2017) adds to McCullough's thoughts:

> In the 21st century, new technologies such as 3D printing and revolutionary ideas like open source have created a new set of circumstances that might finally bring us closer to achieving the dreams of William Morris and the [Arts and Crafts] Movement he inspired. (p. 6)

Verbruggen (2014) and Mäkelä et al. (2016) similarly states that the digital tools have the potential to reverse the power of industry by bringing manufacturing back to the scale of a studio and to the designer. If I contemplate over "digital crafts" or "contemporary crafts", I agree that it opens up certain possibilities and possibly gives traditional crafts a chance to be up to date for today's requirements from the aspects of users and production. In my opinion, we should not feel obligated to get involved in working digitally but still acknowledge that learning about it can expand our perspective for methods and forms possible.

A contrary argument against the notion of "digital tools are not treating crafts but extending the skills" is that digitalization can lead to deskilling. Sennett (2008) explains that historically "skilled artisans faced two potential futures because of technological change: deskilling or dismissal" (p. 107). Digitalization may not exactly dismiss or replace a craftsman or designer but does change the role of them in the production process. In their research, Fyhn and Søraa (2017) discuss this issue through an example of craftsmen working in the building industry. As the production in the industry is becoming more computerized and automated, the nature of craftsmanship in the process is transforming. The craftsmen they interviewed stated that digitalization and automation can never replace them; since "the building process is too unpredictable, you will always need human workers" (p. 72). The aspect that the craftsmen were worried about was not the loss of jobs but "the risk of deskilling, or losing the ability to build houses from scratch" (p. 73). On the other hand, Fyhn and Søraa (2017) state that there is also a possibility of reskilling in this development. The builders now take on more diverse roles such as planning, controlling, problem-solving and improvising. Their craft skills enable them to cope with unforeseen situations, which a computerized machine cannot do.

Mäkelä et al. (2016) and Dufva (2018) believe that digital tools around us constantly transform the ways we understand our surrounding world and may have more influence on the bigger picture. For example, one big question about the impact of digitalization is how will our aesthetical values affected since digital techniques are more suitable for certain forms and surfaces (Mäkelä et al., 2016). "Will it start to dictate what we search for, or can we see the possibilities for new material aesthetics?" (p. 18).

Keep (n.d.) states what matters is that an artist or designer producing work that expresses the time and context they are in. He adds that since we currently live in a digital age, he would expect contemporary work to reflect this. Comparably, in Louridas's (1999) view, when in the past tradition limited the designer's choice and what was anticipated from them, the present designer is expected to go beyond tradition and utilize the contemporary state they belong in novel ways. As we accept all these, I believe that we should still ask how designers can explore the digital in a critical manner.

2.3. *Designer's Position in Digitalization*

Another important question to ask as we are experiencing digitalization and automatization is how our education and work are affected. The practice and role of the designer are continually affected by contemporary circumstances. According to Anay and Özten (2012) digitalization imposes its own dynamics, processes, abilities, and inabilities into the field and rapidly change the ways we think and design (p. 64). As discussions on what the future will bring goes on, it is said that everyone—including designers—will need to predict and navigate within the changing future of work (Pitkänen, 2019).

As Pitkänen (2019) indicates, the profound changes in work will also challenge education and the core skills that are being taught will need to be reconsidered. Leading art and design schools such as the Royal College of Art in London are integrating digitality, including robotics, autonomous vehicles, and artificial intelligence, deeper into their educational structure (Schwab, 2019). In Schwab's view, this new investment of universities proves that today's designers must be trained to tackle interdisciplinary issues that correspond to the present world we live in. She argues that "as technology infiltrates every element of life, the artists and designers who integrate it into their training will no doubt be more in demand than those who do not."

In this situation, the issue is no longer whether to fear the digital or accept it as an opportunity; the matter is going beyond the preference of the designer. Digitalization is proceeding and designers are expected, even forced to some extent, to adapt and work in this new situation. In my belief, when designers are expected to digitalize their approaches, some also need to compromise from their personal identities. While the profession of product design is changing shape into systems and services (Muratovski, 2016), in other words changing into digital product design, me and my peers who gained a craft-oriented and hands-on design education are experiencing anxieties about the future. Kosonen (2018) agrees that the radical changes in the design field during the past ten years cause an "identity crisis" among young designers:

> The changes in design are complex, relating to societal, economic and political factors, such as integration, digitalization, immaterialization, democratization, fragmentation and strategization of design… From the point of view of Applied Art and Design, which typically enjoys hands-on work, a sensitivity to materials, and also manual skills and techniques, this change is enormous. (p. 3)

On one hand, we acknowledge that we do not need to produce more products as we are aware that our consumerist habits are not sustainable. On the other hand, we enjoy being product designers and want to maintain our small-scale hands-on creative processes even if it is not sensible to create new objects anymore. I find it discouraging that it is a necessity to engage more with the digital to be able to find work in the future, due to the discipline being changed. How can I cope with the digitalization while I keep my connection to the hands-on work?

Kosonen (2018) also explains that "for many designers, design is a lifestyle, a way to express oneself in the world, which makes the professional identity more fragile and dependent on personal identity formation" (p. 4). I believe that this was also the main reason why I have positioned myself against digitalization in the first place. Somehow I did not want this concept to be a part of my identity, but at the same time, I did not have a concrete argument why. What did I think it would mean if I were more engaged with digital? Were these thoughts merely based on prejudices? To be able to address these questions, it was necessary for me to be more open towards digital.

As much as it is necessary for young designers to find ways of handling digital development, it is also necessary for educators of design to manage this state. The issues such as what is the designer's position in digitalization, what type of design students are needed in schools, what type of skills should be taught in the curriculum are discussed among educators. Within the range of these discussions about design education, the need for hands-on work among students, and the inclusion of digital tools such as 3D printers are interesting topics for me.

Urmas Puhkan, head of the Department of Ceramics in Estonian Academy of Arts, whom I met during this thesis process, observes that generally students come to the Department of Ceramics with the motivation to work with their hands, and they tend to dislike what is computerized. Even though their department owns various tools for 3D printing ceramics, these tools are in use much less than they estimated. Puhkan comments that it is difficult to come across the type of students who are interested in both hands-on and digital (personal communication, February, 2019).

Another design educator I have met in the duration of this thesis, Oscar Person, an assistant professor in the Department of Design at Aalto University, mentions that it is important to introduce design students to digital tools as early as possible in their education. In this way, future designers would get acquainted with the possibilities of the digital techniques while their perspective on design is shaping; this would allow them to possibly gain a better understanding of what digital means—which is not about "killing the hand". He adds, 3D printing is not in the phase of experimentation anymore; it is time to accept it as common practice in contemporary design and move forward (personal communication, February, 2019)

Part 3:
Improvisation

3.1. *Improvisation in Design*

While I was actively working hands-on with various materials after starting my education in Finland, the way I was working with materials were also changing. I was approaching the craft processes as a way of exploration and learning-by-doing rather than aiming at good or functional objects in the end. One experience I had with the material during a course trip to Nuutajärvi, the glass village in Finland, had a particular influence on me.

Nuutajärvi village, located 2 hours away from Helsinki, used to be the home to the oldest glass factory of Finland that was shut down in 2014. Currently, small-scale glass production facilities, a glassblowing school, and an active community exist in Nuutajärvi (van der Lei & Mavrostomos, 2014). During the trip, we visited the glass school and met the glassblowing masters. We also attended an exercise formalized by Anna van der Lei at this school. The concept of the exercise was each of us to play with glass, a completely unknown material for us, within a limited time of 45 minutes alongside two glassblowing masters. Since none of us had a solid idea about glass material and its production, it was nearly impossible for us to make plans or have preliminary ideas for the outcomes. The process was full of uncertainties and this required flexibility. 45 minutes was very short in reality; we all had to make quick decisions and eventually to improvise along the way.

Before starting, we scanned through the environment we were in, examined the objects and means available, and redefined them as tools to use during the production. While doing so, the primary function of the object was no longer important; only its physical features and how they could work in the process were worthy. The woven mesh surfaces of the metal stools caught my attention at the school workshop. These surfaces made me think that

interesting patterns and textural elements could create on the glass. In normal conditions, the stools are used by masters to stand up while they blow the glass through the long tubes, thus, these stools would never be used as tools to shape the material.

Throughout the exercise, masters we were working with were neither allowed to comment on our ideas nor interfere with our unconscious decisions. In the actual production process, my ideas of achieving textures on the material did not go that smoothly. Half of the stools I selected as tools did not work due to mesh gaps being too narrow for blowing the glass through, and the material was stuck to the stools. I could not have predicted such problems since I did not have any base knowledge of the material. Consequently, I had to be flexible and re-plan my time and tools during the 45 minutes I had.

The masters I was working with, Janne Rahunen and Manuel Diemer, were doubtfully smiling when I asked them to blow the glass through the stools at the beginning of the production. From the master's perspective, going along with a process that they surely know would fail must have been extremely uncomfortable. For masters who are highly skilled in their craft practice, it must be a challenge to go beyond the routines that have been taught to them. Nevertheless, I could observe that Janne and Manuel were also having fun towards the ends of our process.

While improvising this way, one learns to utilize the feedbacks and signs from their actions. Seeing the result of their previous action and planning the next step occurs almost at the same moment. In addition to this, focusing on the process and not evaluating the outcomes as good-bad or functional-useless enables

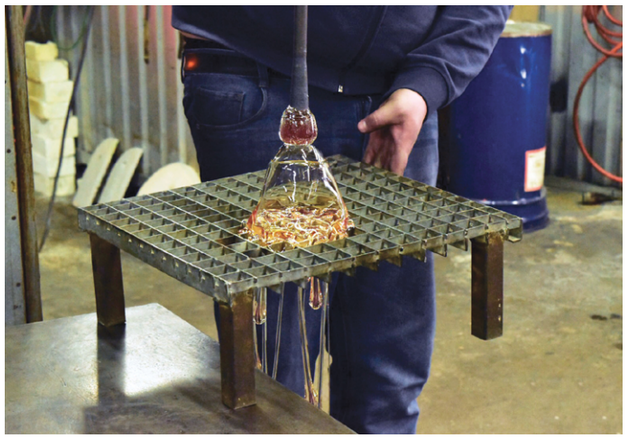

Figure 3. Process of the Nuutajärvi exercise exploring glass within a limited time of 45 minutes and a selected artifact. *First photo by Riko Omata.*

them to lose control. In the end, one does not force the process in order to actualize the outcome they have planned in their minds, rather the process itself controls and shapes the outcome in ways that one cannot think of. Realizing this made me imagine further how I could use improvisation as a designer.

Over the past few years, I have been encountering "improvisation" in different situations and I found myself being fascinated by this approach. Thus, I wanted to explore this interest of mine within the frame of this thesis and understand aspects I found distinctive. My initial understanding of improvisation was that it being the process of exploration and production within the moment, without

a plan, in response to the environment. What intrigued me the most was the chance that this process could result in new patterns, structures or practices—results that could not be designed on paper beforehand.

Essentially, there is always some form of improvisation exist within art, design and craft practices. As psychologist Keith Sawyer whose work focuses on creativity and learning indicates, "improvisation is present in all creativity" (2011, p. 651). Frye (2017) who studied the role of improvisation in the product design field indicates that there are no design processes without it and has always been a method while generating ideas. In my opinion, the practice of improvising is still taken for granted within design, applied arts and crafts practices. Since it is an internal part of the process and mostly intuitively done through hands and mind, we are not always aware of it or we do not discuss it as often—or we discuss under various names.

Improvisation has been defined as "[creating or performing] spontaneously or without preparation" or "[making something] from whatever is available" (Improvise, n.d.). In design, it is not a formalized term as in other art fields like music or theatre. Therefore, various similar concepts which connect with the idea of improvisation can be listed. *Designing-by-doing* can refer to designing something at the same time of producing rather than designing it prior to production. In the field of applied arts concepts as *thinking-through-making* and *thinking-through-material* have been acknowledged (Mäkelä, 2007; Nimkulrat, 2012). Other similar terms are *knowing-in-action* and *reflection-in-action* as Schön (1983) uses to describe experiencing, recognizing, criticizing, and restructuring something on-the-spot.

The concept used by anthropologist Lévi-Strauss (1966), *bricolage*, can be understood as an improvisational way of problem-solving as it refers to creating from a range of available things in a given setting. Lévi-Strauss emphasizes that a bricoleur makes do with the means he encounters within his environment; he redefines those means at hand according to the needs of the situation. Louridas (1999) explains the concept of bricolage further in his article mentioning that the bricoleur enters into a dialog with his materials and uses the signs given by them. These signs given by the material create the possibilities to interact with throughout the process of a bricoleur as he constructs his artifacts. The concept of *adhocism*, manifested by Jenks and Silver (2013), very similar to the goal-oriented nature of bricolage, refers to solving a problem in its most fast and efficient sense relying particularly on the limited resources available at hand.

According to Alessandro Bertinetto (2012), improvising in the creative process, or the ability to create freely, becomes possible through "following, changing,

inventing, and evaluating the action's rules in ways that are unexpected and surprising" (p. 129). Rand (1947/2004) describes a similar process of a designer as the following:

> He improvises, invents, or discovers new techniques and combinations. He co-ordinates and integrates his material so that he may restate his problem in terms of ideas, signs, symbols, pictures… He draws upon instinct and intuition. He considers the spectator, his feelings and predilections. (p. 12)

In this sense, in a designer's improvisational process, the elements that create possibilities to interact with are not limited to the signs taken from the materials at hand. Designer's judgment based on their taste, intuition, and past experiences also influence their conversation with the material (Bertinetto, 2012; Fallen, 2008).

Ingold and Hallam (2007) state that in everyday life people have to adapt to unexpected situations and work it out as they proceed. "In a word, they have to improvise" (p. 1). This, of course, applies to the design practice as well. No matter how much things were defined and planned in advance, in the real production moment, unplanned situations arise in the middle of the process. Coessens (2012) believes that "planned structures are easily blown away by even small, unintended details and interruptions of time and space-related [matters]" (p. 3). In my belief, designing can place through instant decisions given at the moment of execution. This way of designing could, in fact, work better in quickly changing circumstances. The outcome of such a process would still be a result of designerly skills and actions, only without a preconceived plan (Sawyer, 2000a).

Gasson (2015) criticizes the way we celebrate designers who produce elegant or convenient products through traditional and defined ways of designing, rather we should be valuing the designers who are flexible and adaptable. She explains why design should be improvisational as follows:

> We talk about design as if it were fixed: as if there were one best way to design everything… Designers are taught a repertoire of designs-that-works: patterns that fit specific circumstances and uses… The problem comes when a designer is faced with a novel or unusual situation that they have not encountered before… [Design should be] the application of "best practice" principles to a specific situation. (para. 1-2)

Originally, I linked the idea of improvisation in design with concepts as bricolage and adhocism, and by this, I meant the ability to create without prior planning and using means at hand. Yet, my understanding of what improvising meant has largely expanded when I dived into the theories in performing

arts fields—such as music and theatre—where the practice of improvisation is broadly developed and discussed. Through the combination of my past personal experiences and my in-depth reading of the theories in jazz and improv theater, the behavior of improvising became my initial driver for the start of this thesis and stayed as an inspiration throughout the process.

3.2. *Improvisation in Performing Arts*

I did not have any connection to performing arts fields prior to this thesis. However, as I was trying to understand the humanly behavior of improvising, I came across to fields of jazz and theatre and I became fascinated by their theories on improvisation. This further developed my interest in the concept and its relationship to the creative process.

According to Bjerstedt (2014), "art forms, or artists, tend to mirror themselves in each other in order to understand themselves better" (p. 28). I agree with this owing to the fact that after studying improvisation from the perspective of other fields of art, it has become a theoretical tool that allowed me to make sense of my own creative process and see more possibilities in my own field. It made me realize how special this skill is and should not be taken for granted.

Generally, the word "improvisation" is understood in various ways by individuals. In casual language, it is perceived as the magical moment of spontaneous and intuitive creation. For some, it may mean coming up with something entirely novel right in the moment. What is generally unrecognized is that, to achieve new results while improvising requires base knowledge and frequent practice. Improvisation is never coming out of nowhere; "there is always a background upon which improvisation will take place" (Bertinetto, 2011, p. 96). As I was gaining a better understanding of what improvisation means in performing arts fields, I realized that it is not solely spontaneous or intuitive. Rather, it is largely dependent on knowledge and it is something one can learn and practice to use in their future creative process. For this reason, professionals in the field indicate that "improvisation isn't really that creative, or, at least, it's less creative than most people think it is" (Becker, 1982, as cited in Sawyer, 2000a, p. 181).

> **...A common misconception about improvisation is that the performers are playing without any preparation... No performer ever makes up everything from scratch every time. There is a constant balance between**

> **preparation, tradition, and spontaneous creativity. No matter how spontaneous it sounds, there is always some structure that holds the performance together and guides the musicians... (Sawyer, 2011, p. 650-651)**

Within the performing arts, improvisation is a largely formalized practice with defined techniques. Such techniques are set on the practice of learning to utilize the existing knowledge to introduce new structures and results. Therefore, improvisation exists in the combination and balance between structure and creativity, and spontaneity and tradition (Bjerstedt, 2014; Sawyer 2000a). Bertinetto (2013b) points out that there are different approaches to improvise and one can decide how much freedom and rule they will let into their process. He adds that some improvisational practice can be more "experimental, free and unrestrained" whereas some can be more "controlled and bounded to different kinds of constraints, contexts, instructions" (p. 8). Sawyer also emphasizes that there is no certain division between "improvisation" and "not improvisation", "rather, there is a continuum, from more improvised to less improvised" (Sawyer, 2000a, p.182). Either way, the process is aimed at the variation, combination, and rearrangement of existing knowledge and methods—with the use of intuitive and creative freedom—would result in new possibilities and go beyond repetition.

> **...Improvisation shows how artistic creativity unfolds by shaping and reshaping procedures, traditions, styles, genres; by following and inventing rules of acting; by failing and succeeding; by accomplishing fairly –if it succeeds– something unexpected, valuable, unrepeatable, and exemplary. It shows that – in art, as in life– failures and mistakes can be turned into chances for unpredictable, original and exemplary achievements... (Bertinetto, 2012, p.135)**

Improvisation is often experienced in a live setting where actions in the creative process can be observed by an audience in a real-time moment. This type of "liveness" requires the performer's skills, resources and practice in order to enforce real-time decision making, or in other words "think on-the-fly". (Sajnani, 2012; Bresnahan, 2015). "Each move [in the performance] implies

that parts disappear and others appear, so that in each situation a [improviser] can make only one choice at a time and can never return to the crossroad where he/she had been a moment ago" (Coessens, 2012, p. 1). This makes the creative process irreversible in the sense that it cannot be corrected afterward unlike a designer's or artist's opportunity to revise their work. (Bertinetto, 2012; Sawyer, 2011). The process results in outcomes that are usually unrepeatable; therefore they remain exemplary. Even if a similar improvisational routine led to the original production would be followed, the result would not be identical (Bertinetto, 2011, 2012).

Observations from a Musical Performance

Sawyer suggests that "improvisational performance is the creative process made visible" and this gives a chance to observe how creativity works in development. Therefore, "improvisation can teach us about the creative process in general" (2011, p. 651). As I was reviewing the theories of performing arts, I wanted to attend a real performance as an audience and observe the process in the live moment. Luckily, during the period of my research, I have come across a musical improvisation event: the fourth session of Summer Improv Series held at the Museum of Impossible Forms in Helsinki, where local and international improvisers meet up on stage to create performances.

The first improviser I was observing was cellist Sergio Castrillón. His performance was highly experimental; and the first emotion I experienced was confusion. My immediate reaction was to judge the musician's output since it was very beyond the conventional. I had to remind myself that improvisation is not about the outcome but the process. After this state of bewilderment, I was able to focus more on the musician's process by watching his movements closely and trying to make sense of his actions and decisions. I felt like I was able to understand the reasoning for most of his actions due to my readings on improvisation in the fields of performing.

My first observation was that the musician was constantly exploring his cello, using it in every possible way. Just as a bricoleur uses the means in the given setting, he was using what was available at his hand. In order to do so, he sometimes had to alienate his instrument from its primary function. He did not limit himself only to use the strings, but he explored the surfaces and edges of his instrument to see if he could find any new meaningful way to make music. I felt like the elements he seemingly casually discovered while playing was enabling him to connect to his instrument, his tool further. This made me think that improvising is a practice in which the act of production and personality are intertwined; where one can make discoveries about themselves and their

practice. It reminded me of a quote: "Improvisation is about following your inner impulses… Essentially it is about the courage to be yourself. It is about the direct impulses, about not thinking too much" (Soenarso, 2013, as cited in Bjerstedt, 2014, p. 22). Another observation of mine was how the musician was flexible in his production process. When a string of his cello broke, which traditionally would have been defined as failure, he immediately turned this situation into a means of production. He started to explore the possibilities that the broken string might bring for making music.

3.3. *Elements of Improvising*

To understand the artistic creativity underlying in improvising, Charles Limb studied the issue from a neurological point of view. As a neuroscientist and a musician himself, he designed a special musical keyboard that could be used during fMRI to research how the brain functions during musical improvisation. In his talk, Limb (2010) compares the results of brain activities while playing a memorized and improvised piece of music. Results showed that self-reflection and autobiographical activities increased in the brain when the subjects were improvising. Another finding of his study was that during improvisation, brain minimizes the control mechanism for actions taken and subjects are more willing to make mistakes. This seems to mean that, in the neurological level, improvisation initiates being less concerned about the outcomes of a creative process. It seems to free one's mind of expectations and fear; seems to make one coming closer to themselves by letting go of control in the process.

I believe these aspects would be valuable in the processes of design, applied arts and crafts as well. Indeed, the Nuutajärvi experience I have mentioned earlier included all the significant elements of improvisation: producing in a determined setting in a limited time, embracing uncertainty, relinquishing control and taking risks, overcoming the fear of failure by focusing on process rather than the outcome.

Process over Outcome

Design practice traditionally tends to be outcome oriented; the purpose is to come up with a solution or a product in the end, and the creative process acts as a way to reach that final product. Sawyer (2000b) explains that this type of creativity, which leads up to a product at the end, is "product creativity" which involves long processes that start with a plan and hold opportunities for revision. In the opposite case, in "improvisational creativity", the process is the product. Sawyer also addresses that improvisation is emphasizing on problem-

finding rather than problem-solving. In a problem-finding approach, the goal is to see what comes out of the process rather than trying to execute a certain idea or result in mind.

The process of improvising requires continual exploring, experiencing with possibilities, and taking risks without knowing how the actions will unfold (Lacerda & Chung, 2013). Prabhu (2011) explains: "People who take risks are not afraid of the unknown—in fact it is the unknown that arouses their curiosity. They are open to implementing ideas which may have uncertain outcomes" (p. 322). In order to do so, it is a necessity to overcome the fear of making mistakes or fail. Since improvisation is all about the process and there is no certain expectation, the distinction between success and failure becomes less definite. When one understands that they cannot fail if the process itself is the outcome, it lets them free their minds, and even to relinquish the control in the moment of producing. 'One musician in Sawyer's interview study [describes] that "if you reach that point, it would be freeing, to free your ears to play a note that normally wouldn't belong there"' (as cited in Bjerstedt, 2014, p. 59).

Uncertainty and Adaptability

Bertinetto (2013a) explains the unpredictable nature of improvisation as follows:

> Not only may accidents of several kinds happen during a performance, but every performance of the same work is different from every other… Performers are in principle exposed to situational (emotional, ambient…) factors that they cannot completely control and to which they have to respond properly 'on the spot'… In artistic improvisation performers continuously respond to unforeseeable contingent emergences (p. 129).

According to Sajnani, (2012),"to improvise is to risk stepping into the unknown" (p. 81). In order to tolerate uncertainty, one needs to be flexible and adapt to situations easily. This means that instead of trying to change the process to meet one's own needs, one needs to adapt themselves to the process and accept and respond to events occurring. At the beginning of an improvisational state, there is a lot of uncertainty; there is not a plan or frame to the production. Shortly after the start, a large number of parameters to play with arises (Sawyer, 2000b).

Improviser uses the "continuous feedbacks loops" occurring, evaluating the creation as it is happening and using the emerging possibilities immediately. The way of doing keeps to evolve within the process (Bertinetto, 2012; Schön, 1983). Listening, following and remembering is important in order to progress; thus, high awareness of the process and the situation being in is required. While

improvisers produce at present, they are aware of the earlier parts of their performances and their progress is affected by their past experiences. The new elements, rules, and structures that are emerging also become the knowledge for further improvisations (Bertinetto, 2012; Bjerstedt, 2014).

Therefore, improvising is a constant process of know-how creating and every knowledge emerged within the creation—failed or succeed—has value. As Cohen (2011) explains, in an uncertain process where risks are taken, there is always a dynamic element of chance. "People can actively and randomly explore new ideas or work processes. Although randomness may be inefficient, it can lead to 'lucky' breaks" (Cohen, 2011, p. 14).

Embracing Mistakes

"Do not fear mistakes—there are none" says Jazz musician Miles Davis in his famous quote. Bertinetto (2016) explains what Davis's words mean is that since improvisers do not follow a score while they are performing, there is no rule to violate, and therefore, nothing to be considered as a mistake. Bertinetto adds "mistakes do not exist, unless we use and consider them as such" (p. 98). The fact that something appears as a mistake is only because of the norms and expectations we have been taught.

Bertinetto (2016) indicates that "playing against the normative expectations" is a feature of improvisational practices, especially in jazz (p. 87). Boyle (2012) also points out how "musicians speak of 'learning the rules' in order to 'forget them' when playing" (p. 7). This approach in jazz improvisation can teach one to go beyond rules, routines, and find the charm in failures (Weick, 1998). I believe this may also enable a designer focus more on the process and exploration rather than fearing the result. In Bertinetto's view (2016), artists—and designers—who can modify the normative background of their practice can lead to changes in those norms.

"Sometimes unpredicted and unwanted accidents that might seem to damage or destroy the aesthetic/artistic quality of an artwork or of an art performance may turn out to be lucky contingencies after all" (Bertinetto, 2013a, p. 126). This situation also connects to the term serendipity, known as the unexpected positive discoveries by chance (Lacerda & Chung, 2013; Horan, 2011). These unexpected and serendipitous elements can allow artists to naturally explore and develop new ideas, forms, and expressions. This happens particularly successful when one is prepared to deal with those lucky emergencies. In other words, when one sees the "creative potential of the destructive event [and takes] it as a lucky chance" (Bertinetto, 2013a, p. 127).

Schultz (2009) expresses that "we may not know exactly how we are going to err, but we know that the error is coming, and we say yes to the experience anyway" (as cited in Boyle, 2012, p. 7). Embracing a mistake means accepting it as a sign guiding the progress of the process. The point is, instead of thinking about how to stop making mistakes, seeking how to take advantage of them. Another quote from Miles Davis explains well how a jazz musician approaches mistakes: "It's not the note you play that's the wrong note—it's the note you play afterwards that makes it right or wrong" (as cited in Bertinetto, 2016). This reveals that as long as one knows how to act on the mistakes and make them right, their process will not fail. From one point of view, "an improvisation is actually nothing but a series of corrections" (Bjerstedt, 2014, p. 20). Therefore, improvising is also about the real-time relationship between error and choice.

Nonetheless, serendipity does not have to be truly natural or unexpected; lucky chances can be planned to be produced intentionally. According to Bertinetto (2013a), improvising is also about learning to make voluntary mistakes and practicing to achieve serendipity. While we recognize that unintentional mistakes act as artistic resources; we should acknowledge that learning how to make mistakes intentional can even become a greater impact on the creative process. The possibility of lucky surprises enhances if one steps outside the boundaries of their comfort zone, and intentionally expose themselves to risky situations (Bertinetto, 2013a).

Part 4:
Approach

4.1. *Improvisation within Digitalization*

What digitalization meant was not only an unknown to me; the uncertainty of digital technologies had an impact on every part of the contemporary society, and discussions take place in the context of different disciplines (Dufva, 2018). As digitalization develops and every discipline goes through changes, the processes, approaches, and skills needed for the future are also altering. Pitkänen (2019) explains some of the critical skills needed for the future of work as the following: situational sensitivity, adaptation to fast-changing situations, self-awareness, ability to cope with what seems destructive. Sterling (2005) also points out that a future society has to be "prevail against the unforeseen" at a great speed (p. 47). Therefore, making fast decisions, keeping a record of all trials and errors, and learning from these experiences will be more valuable rather than reasoning out a solution beforehand (Sterling, 2005).

I realized that the values I have studied in improvisation linked to the necessary skills of a rapidly changing society, in addition to many values it provides for the creative process. Gasson (2015) notes that improvising is a useful skill to adapt to various unusual or novel conditions, in order to apply the most convenient practice in a specific situation. Gerber (2007) suggest that jazz and theatre improvisation can introduce techniques to support the contemporary formulation of the designer's work. It can help a designer to discover possibilities and ways to deal with their transforming role in a continually changing field—especially with the digitalization. Bertinetto (2013b) also states, "while improvising a solution to an unexpected problem, we can achieve a practical experiential knowledge about how to act in some unforeseen circumstances" (p. 1) which corresponds to Sterling's point mentioned earlier.

> **...The word improvisation itself is rooted in the word "proviso" which means to make a stipulation beforehand, to provide for something in advance, or to do something that is premeditated. By adding the prefix "im" to the word proviso... improvise means the opposite of proviso. Thus improvisation deals with the unforeseen, it works without a prior stipulation, it works with the unexpected... (Weick, 1998, p. 544)**

This aspect of improvisation eventually became interesting to utilize within the investigation of my problematic relationship to digitalization. When my thesis advisor Maarit Mäkelä, who is a ceramics artist herself, suggested that 3D printing clay may be an interesting case for studying improvisation

in this sense, I was interested and skeptical at once towards this idea. As I acknowledged that studying a traditional craft as ceramics being digitalized was a good case for my research, the idea that my master's thesis would be about 3D printing was somewhat difficult to overcome. I believe, what made this difficult for me was due to Kosonen's (2018) argument cited earlier—how many designers perceive the work they do as a reflection of their personal identity and expression. I have perhaps not imagined myself as a designer whose practice is 3D printing.

In the meantime, at the Department of Design in my university, the presence of 3D printers was rising. There has been a recent purchase of a big-scale clay printer aiming to open up new possibilities for ceramics practice at the university and there were ongoing plans to integrate ceramics 3D printing into the bachelor's curriculum. I realized that I should overcome my prejudices and explore something unknown to me. As I kept stating that I have a problematic relationship to digital, I have actually never openly and critically engaged with a digital tool. Therefore, 3D printing clay represented a medium of investigation for me to analyze my relationship to digital and hands-on.

Ultimately, my research has formed a bridge between the two different issues that were simultaneously influencing and shaping my thoughts as a designer: my concern for being in a digitalizing field and my interest in improvisational processes. While working with the 3D printer, improvising allowed me to produce in the unfamiliar and uncertain setting I have entered. As I approached improvisation as a tool for being spontaneous, flexible and relinquishing control, it enabled me to find a personal way of working hands-on within a digital process. Mäkelä (2007) explains how artists and designers embrace theoretical tools "to be able to give a certain structure and find a suitable context for interpreting and handling [their] practice-led research projects" (p. 160). Concept of improvisation worked as my theoretical tool, or a simpler way to recognize and explain the actions I take during my creative process.

4.2. *3D Printing and Clay*

3D printers have been around us for a long time now and they have a part in digitalization of production both in an industrial and personal level. As a means of digital production, they have been drawing the most attention since they have been one of the most affordable and accessible tools for the common user. Hong (2018) states that "as technical advancements in both hardware and software further accelerate and knowledge is more actively shared, 3D printers will become more widely used and their influence will grow" (p. 106).

As 3D printing technology has been rapidly developing in a period that I was a product design student, I have been around these machines. My first conceptions of 3D printing were based on the value that people attributed to this technology. There were always great expectations and scenarios on what could 3D printers do in the future; how they could change the way we live and fabricate. My own experiences with the 3D printers around me, on the other hand, were far beyond this conception. Whenever I used them, the process was full of errors and failures; and I have never got a smooth printed result at the end. It was hard to imagine how this imperfect technology could have a huge impact in the future.

Today, 3D printing is still speedily developing; expanding further into different fields and various materials. In this realm, clay has also been acknowledged as one of the suitable materials for printing by artists and designers (Hansen & Falin, 2016). Since clay is a responsive material, ways to manipulate it is in a wide diversity: clay can be formed by hand, thrown in a wheel, slip cast, and now even 3D printed. Through the development of ceramics craft, new tools have always expanded "the possibilities for new shapes, purposes and functions" (Hansen & Falin, 2016, p. 115; Mäkelä et al., 2016). This continues in the digital state today.

Even if the 3D printing technique can be still considered as new, the clay material is instantly recognized and respected by people since it is known for thousands of years (Keep, n.d.; Mäkelä et al., 2016; Verbruggen, 2014). The technique that the printer uses, layer by layer extrusion, is also very similar to coiling which is one of the earliest techniques of traditional pottery that the humankind used to create utensils. Therefore, Verbruggen claims that 3D printing clay is not something high-tech but simply computer-based coiling (Hansen & Falin, 2016; Verbruggen, 2014).

Exploration and use of 3D printing in the field of ceramics are growing with the open-source printers which can simply be built based on instructions accessible online and parts that can be gathered from a hardware store. Pioneers in this area are Belgian design studio Unfold and British ceramics artist Jonathan Keep. Unfold adapted the delta-type 3D printer—which was widely used by others—into a clay printer. The open-source nature of this printer allowed them to customize the machine for their own practice, as they were aiming to escape the ways of making dictated by the availability of digital tools (Hansen & Falin, 2016). Jonathan Keep followed Unfold and their printer set-up, modified it for himself, and eventually shared the plans of his printer over the internet along with the documentation of his building process (Keep, n.d.). Keep's plans and documentation is widespread today and serves as a guide for common users and designers who want to build their own clay printer. Keep explains that:

> There is enough information out there on the internet for somebody with reasonable DIY skills to acquire all the bits, and while not fully understand all the complex computer engineering and software development, to put a working 3D printer together as I have done. (Keep, n.d.)

Different artists explore this new medium through their own terms. Lauerman (2014) explains some might use this technology for practical reasons such as to achieve a smoother finish or to duplicate forms. Others can use it to explore novel shapes, new aesthetics, and techniques for ceramics production. Dries Verbruggen from Unfold describes how they use the 3D printer as a medium to "investigate new ways of creating, manufacturing, financing and distributing in a changing context. A context in which [they] see a merging of aspects of the pre-industrial craft economy with high tech industrial production methods and digital communication networks" (Verbruggen, 2014, p. 173). Jonathan Keep explains that he did not want to use the 3D printer as a manufacturing method, rather intended to incorporate it into his creative process. He did not want to send the digital files off to a company to print but he wanted to have the printer as a tool in his studio alongside his pottery wheel (Keep, 2014). Keep also states that his traditional ceramics work has always been characterized by a strong sense of form, therefore emerging technologies such as 3D modeling and printing offered him new ways to manipulate forms, explore complex shapes and volumes that he could not have envisioned without the use of a digital tool (Keep, 2014).

Nevertheless, the practice of 3D printing clay is still based on hands-on experiences to a large extent, even if it takes shape in a digital space. First of all, the process requires skills to work with the clay material. Verbruggen (2014) describes, "clay needs to be meticulously prepared and loaded inside large syringes; material flow needs to be guarded and adjusted during printing. Printed wares need to be finished, glazed and fired" (Verbruggen, 2014, p. 176). Second of all, during the process of printing, many errors and mistakes occur, therefore, the process still requires a human to control and solve problems. Even though the 3D clay printer is computer-based, it is not a perfect machine. Consequently, this medium presented an ideal ground to investigate my position between the digital and hands-on since the process involved both aspects. At the same time, clay was a sustainable material choice for my purpose, which was based on exploration and investigation rather than production, as it can be easily recycled and re-used when it is not fired.

In the beginning, I was asking myself what it meant to print clay and how did this connect to ceramics craft. At this point, I am convinced that 3D printing clay is not an extension of the traditional craft of ceramics, but can be seen as

a whole new practice in itself. Clay printing is not exactly the digitalization of ceramics; it does not merely automate the traditional ways of working with ceramics but it defines new ways and aesthetics.

4.3. *Methodology: Practice-led Research*

From the very beginning, my approach in this thesis has been in a subjective manner. Since my motivation in research was investigating my chancing discipline, questioning and transforming my own practice, *practice-led research* became the main methodology. According to Mäkelä (2007), this type of research is "characterized by a focus on issues, concerns and interests that are explored and manifested through the production of creative artifacts" (p. 159). Muratovski (2016) agrees that practice-led research is "an integral part of the work of designers because this allows them to continually challenge themselves and the conventions of their profession" (p. 191). As it is understood, this approach is highly focused on self-awareness and self-learning. Therefore, the activity of researching also becomes a personal and demanding state of consciousness that goes beyond routine research processes (Pedgley, 2007).

Fallman (2008) similarly explains that *design exploration*—which I believe is a part of practice-led research—becomes a way to comment, make a statement or discuss an ongoing societal situation that affects the discipline. In my case, through the practical process I had with the 3D clay printer, I was able to address wider issues such as digitalization. Practicing "making" encouraged me to ask new questions and gain new perspectives. According to Mäkelä and Löytönen (2012), researching, making and learning are all intertwined in an open-ended process of the practice-led research. Artifacts emerged during the course of making, on the other hand, are not the main focus, rather they support the research. They function as "means of realizing" as they become tools to collect, preserve and understand information. Therefore, they have to be understood and analyzed after their emergence (Mäkelä, 2007). Nimkulrat (2012) considers, "a way of knowing" is emerging from the interaction between the researcher and the artifacts.

Besides practicing making, practice-led research uses methods of *autoethnography* such as self-observation, self-dialog, and reflection. As an approach, autoethnography combines elements of autobiography and ethnography and "seeks to describe and… analyze personal experience in order to understand the cultural experience" (Ellis et al., 2011, para. 1). According to Ellis et al. an autoethnographer believes that research can be personal, theoretical, analytical, emotional, therapeutic all at once (para. 39). This connects with the central motivation of practice-led research.

> **...Each person's life is a quest or struggle to make sense of experience, to grasp what personal experiences mean, and express those meanings to one's self as well as to other people... As humans we seem compelled to make sense, to find meanings, to grasp the ungraspable... (Bochner & Ellis, 2006, p. 3-4)**

While "autoethnographer's story theorizes personal experience" (Bochner & Ellis, 2006, p. 5), it should not be understood solely as the writing of selves. Autoethnography stands between subjectivity and analysis. Personal experience becomes valid only when it is analyzed and extended to a wider social and cultural context that the researcher belongs (Bochner & Ellis, 2006; Denshire, 2013). The form of reporting also differs in autoethnography from other research approaches. According to Ellis et al. (2011), "by producing accessible texts, [researcher] may be able to reach a wider and more diverse mass audience that traditional research usually disregards" (para. 14). Instead of abstract and impersonal texts, personal yet scholarly narratives and first-person language are used to connect with the audience. Reading one's autoethnographic research may also evoke self-examination in the reader (Chang, 2008).

Researcher's reflection is highly important in practice-led research. Johns (2009) explains that the ability to pay critical attention to actions in the process allows the researcher to learn from their experience. According to Mäkelä and Nimkulrat (2018) "reflection conducted at different stages of the project may provide the primary material for communicating and sharing the experiences related to the project" (p. 2). The outcome of my research is based on the experiential knowledge gained in the process by reflecting in and on action. As I reflected during my practice, I was aware of the ways I was thinking, feeling, and responding (Johns, 2009, p. 10; Schön, 1983).

While I was producing artifacts, using a journal was the main tool to document, analyze and reflect. I used reflective journaling as a method to collect experiential knowledge. Developing a daily writing habit enabled me to capture, record and interpret my process, actions, feelings, discoveries (Mäkelä & Nimkulrat, 2018). Even though I was continuously reflecting during making, this was not a written process. Documentation happened not within the production moment but afterward. This way, I could give all my focus to making and responding on-spot. In the evening of each day I spent working with the 3D printer, I filled one or two pages reflecting and analyzing. Just as making, writing also acted as a thinking tool for me. Writing was not only to document but it was about entering into a self-dialog and exploring arguments. Besides writing, I found joy in rapidly illustrating each artifact produced that day.

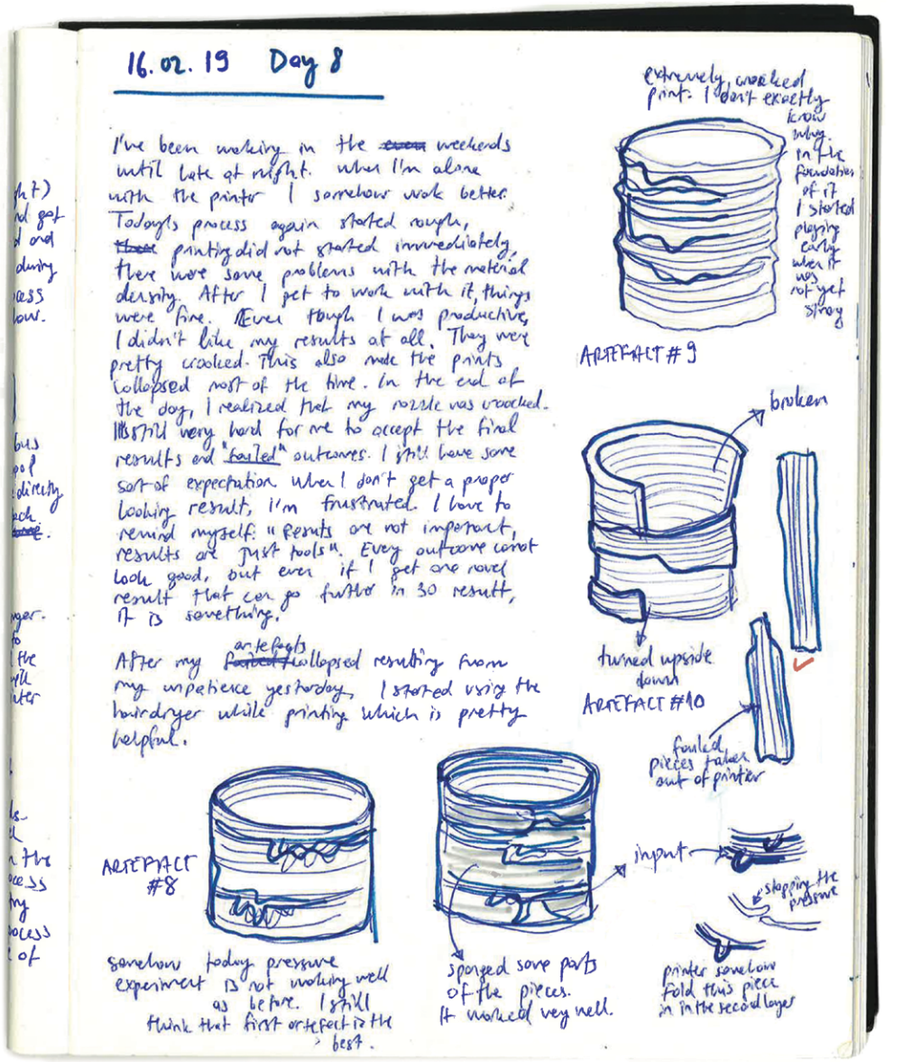

Figure 4. Page from my logbook: Day 8 in the process expressing my frustration resulting by identifying certain artifacts as "failed".

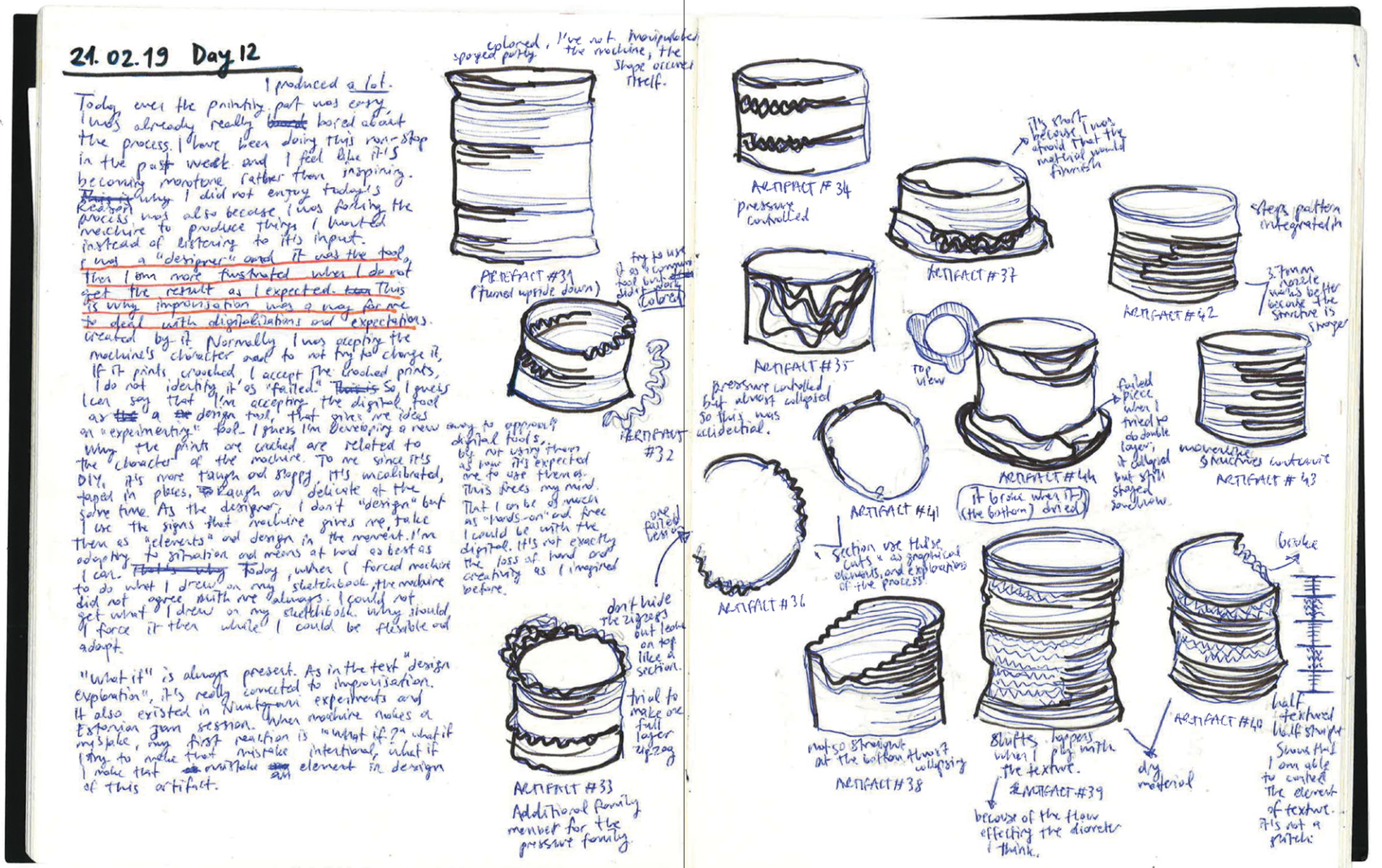

Figure 5. Pages from my logbook: Day 12 in the process visualizing artifacts and explaining the ways I learned to interact with the machine.

Part 5:
Process

5.1. *First Encounters*

The Machine

The practical part of my study took place at the university 3D printing workshop—belonging to the School of Arts, Design and Architecture—over the period of 3 weeks. There were two different types of clay printers that I could work with: one was the newly bought professional WASP brand printer, and the other was the do-it-yourself (DIY) printer which was built by Jonathan Keep's instructions—previously mentioned in the text. I referred these machines as "big printer" and "small printer" as I was describing them. The big printer could print up to the height of 1 meter and the diameter of 30 centimeters whereas the small one could only print approximately height of 20 centimeters and diameter of 10 centimeters. Both of these printers were delta type printers, similar in construction and technically they worked in the same way.

A delta 3D printer adapted for clay consists of several main parts as Segura Gonzàlez (2017) explains. The pushing system—which was the air pressure in the printer I use—applies a force to the material inside the cartridge to extrude it through a nozzle. The feeding system consists of a cylinder cartridge where clay is filled and a nozzle attached to this cartridge where clay flows out. The slider frame is composed of 3 motors and 3 arms that carry the feeding system. These arms are attached to 3 posts that form a triangle. In a delta printer, the printing plate is fixed and the arms are in constant motion in X, Y, and Z axes (Segura Gonzàlez, 2017).

The DIY version of the delta printer was far more exciting to me. It was built 3 years ago by another student, Ashish Mohite, for his own thesis work; and since then it has traveled around the campus, from the Department of Mechanical Engineering to the Department of Design. Currently, the machine was not used regularly by students, so the condition or calibration of it was not at its best. This printer, which was fixed with tape and other makeshift methods, looked rough and delicate at the same time. Its imperfect look made me feel like it was a "friendly tool", not a frightening digital machine (Sennett, 2008). Therefore, it was a good place for me to start exploring my relationship with digitalization.

Additionally, this printer required a continuous pressure control by hand which instantly made it more hands-on and generated possibilities to improvise and intervene. In the case of the professional printer, the pressure was adjusted automatically by the machine itself through a calculation of the remaining material and print speed. Thus, it did not require a human to be present in the process. For me, controlling pressure by hand represented one way to communicate with the digital machine.

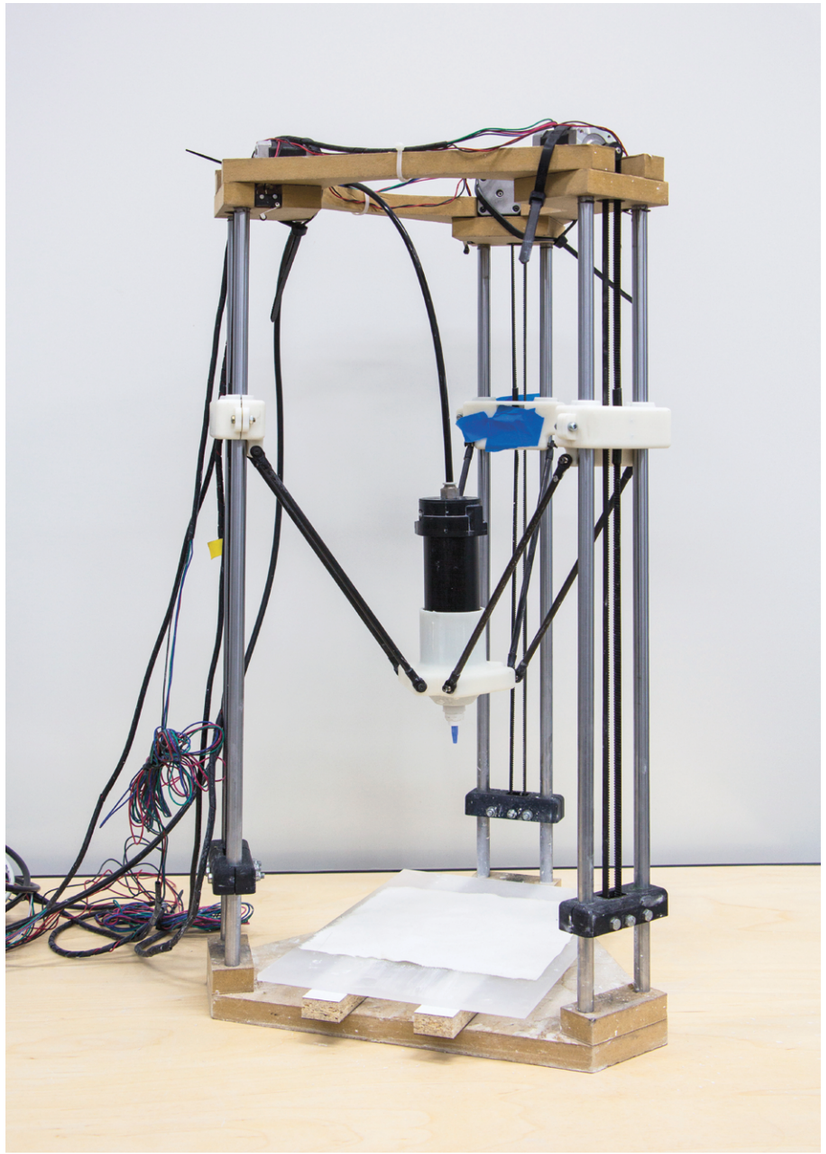

Figure 6. The 3D delta printer I worked with during the process, built by Ashish Mohite.

In fact, it was not the first time I have encountered this type of DIY clay printer. In 2016, in a course that I attended during my bachelor's studies, I took part in a team that built an identical machine. The motivation of this course was investigating potential ways to expand the designers' toolset by building machines. Working as a group of 20, where students and the instructor Benay Gürsoy Toykoç worked in collaboration, we have built Keep's open-source clay printer. I was a part of the construction sub-team focusing on the physical aspects and components of the machine. Thus, I was not familiar with the electronic aspects, firmware or coding. After completion of building the machine, we did not have a long time to experiment with printing. For this reason, I could say that I had some sort of "base knowledge" about this printer and its physical sides, but not about its process. It appears that I was not interested enough in this digital tool at the time, that I did not remember the period of working with it very clearly; it feels like encountering an old friend I have known before, but at the same time, it is entirely new and unknown.

Frustration

Even though I was motivated to start working with the machine, my first encounters were based on immediate struggles with the digital. Starting from my first usage, I realized that communicating with this machine would be a challenging process. For example, the very first problem I have encountered was not being able to connect my computer to the machine. Workshop master Manuel Fonseca, jocularly, attributes this to the fact that the machine had its own character and ability to choose which computer to connect to. He, as well, did not have a rational explanation for this problem. The problems were already occurring before the printing process, and in the end, even if I could achieve to start printing, nothing solid could result. As the machine created errors and glitches—which were the aspects that I was excited to take as possibilities—it was almost impossible to print anything structural in this condition. Ceramics workshop master Tomi Pelkonen refers to these results as "a pile of noodles".

The previous understanding I had was that something digital should be working flawlessly. As I kept confronting the realities of digital fabrication, I was questioning my printer choice and whether if my frustration was based on the limitations of the DIY machine. Even if I have chosen the "imperfect" printer in the workshop, the situation was no different for the workshop masters Tomi and Manuel, who were trying to operate the new "perfect" printer; they were experiencing problems in different levels as well. McCullough (1966) expresses how "there has never been an ultimate medium, and craftsmen of all past ages have exhibited patience, sympathy, and innovation with their imperfect… media" and adds "the same will be true for

Figure 7. Workshop masters learning to operate the new WASP clay printer. *Photo by Minerva Juolahti.*

the digital realm" (p. 143). I realized that all digital tools which are expected to produce perfect outcomes have their imperfections in their own ways, whether it is DIY or professional. It is a learning process and the only way to get through is getting used to the machine you are using. McCullough (1966) states that "the crude technology may seem overwhelming" and one who is using digital tools has to learn how to "work around psychological-technical barriers" (p. 143).

The most frustrating aspect of this period was knowing what the same DIY machine is able to do in its normal state. Being excited about the possibilities but not being able to get the machine working, or not even being able to understand the reasons to prevent it from working was what made me most discouraged. In this unfamiliar process I entered, the cause of the problems were widely ranging from coding to modeling, from mechanics to material skills. This made it challenging to spot what was wrong. The process was

also dependent on digital structures such as firmware, software, and even the internet connection. Different from directly working with materials and hands, the problems here were less communicating with me, and therefore, less accessible. Most of the time, I believed that I was becoming demotivated faster than usual when something went wrong. My consideration was that if this was a hands-on process I would have more control of problems in the process, at least I could understand what the problem was.

It was interesting to compare how the experience of working with the same material could differ. When working with clay through my hands, I am usually experiencing a peaceful, calm and slow process; oppositely, while 3D printing clay, I was impatient and expected things to result fast. This was perhaps the idea of digitalization in my mind implied that a digital fabrication process must be fast and efficient. At some point, I have acknowledged that the digital process needed patience and slowness just as a traditional process would need. In order to start working with the printer, I first needed to have a structure, a base, a clear understanding of the process. After this realization, I started to take the whole progress slower and spent the time to get to know the machine better—how it functions and what are the main issues of it.

I started simply as taking better care of the machine, cleaning its parts on a daily basis; even this helped it to work with fewer flaws. Later on, I put an effort to understand the software and coding aspects which were necessary to transfer information to the printer. These may seem simple and obvious, yet it was difficult to come to the realization that the digital machine needed more of my involvement and effort to function better. In the end, I started to get used to the routine of the process. Through understanding the main properties and issues of the machine, I developed my own agile ways to fix them. As the unfamiliar machine was becoming familiar, the processes that previously felt very long and frustrating started to become fast and smooth with time.

In the meantime, I have also realized the importance of the context one works in. Space, tools, knowledge of the workshop masters; they all have a direct effect over the frustration or excitement in the process. As Mäkelä and Löytönen (2017) states, I am realizing how the environment has an affordance in the learning: "Physical environments, spaces and relations… open or limit the possibilities for new practices, knowledge(s), networks and relationships to emerge" (p. 251). In my case, during the occasions I worked alone with the machine, the process was more productive. I could better focus both on the dialog with the machine and the dialog with myself. Therefore, for a period, I worked at the weekends when nobody but me was in the workshop; this had a positive effect on me learning to communicate with the machine and influenced the progress of the whole research.

Figure 8.
The printing set-up I worked with at the university workshop.

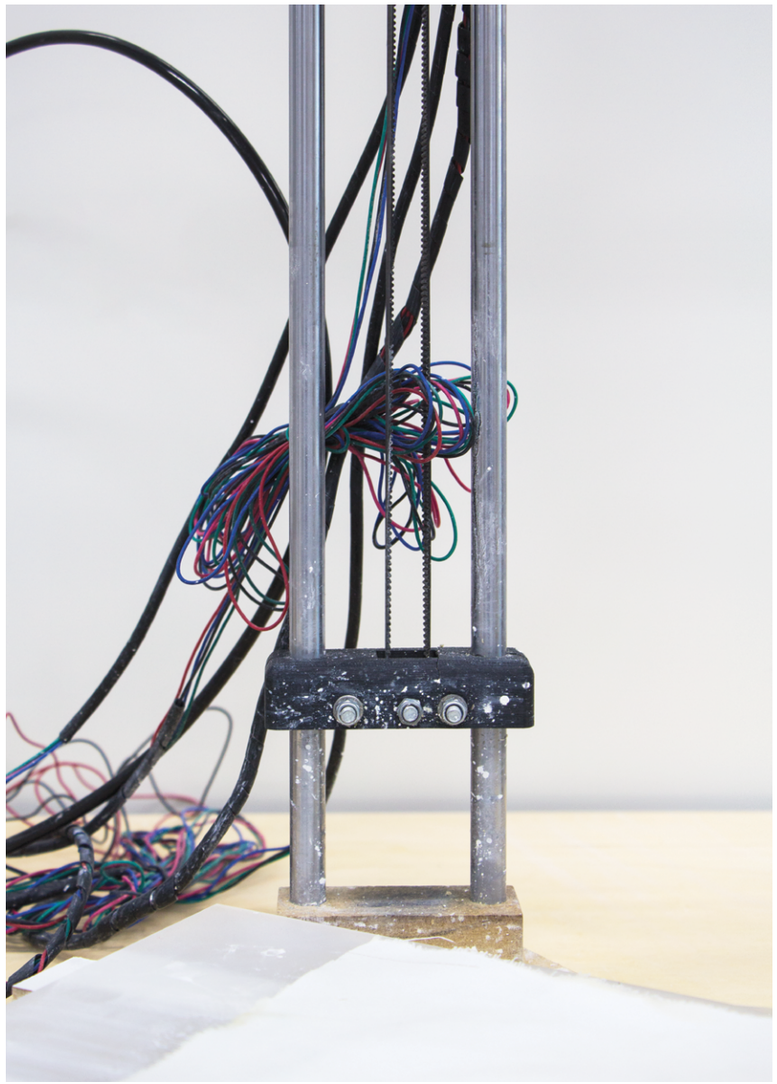

Figure 9. Details from the printer.

Figure 10. Details from the printer, the feeding system with cylinder cartridge where clay is filled.

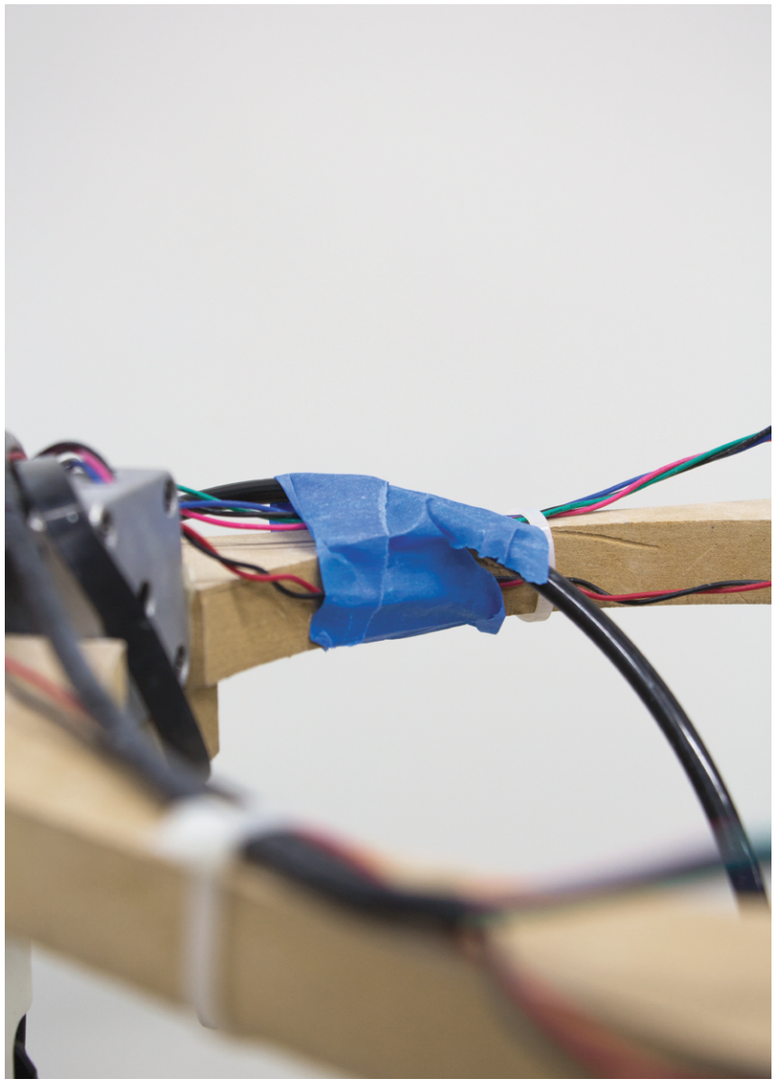

Figure 11. Details from the printer: makeshift methods as tape are used to fix the issues such as tangling cables.

Figure 12. Informal tools of the clay printing process: water applied on the printing plate eases clay to stick and air blown with a hair-dryer during printing helps artifacts to dry faster.

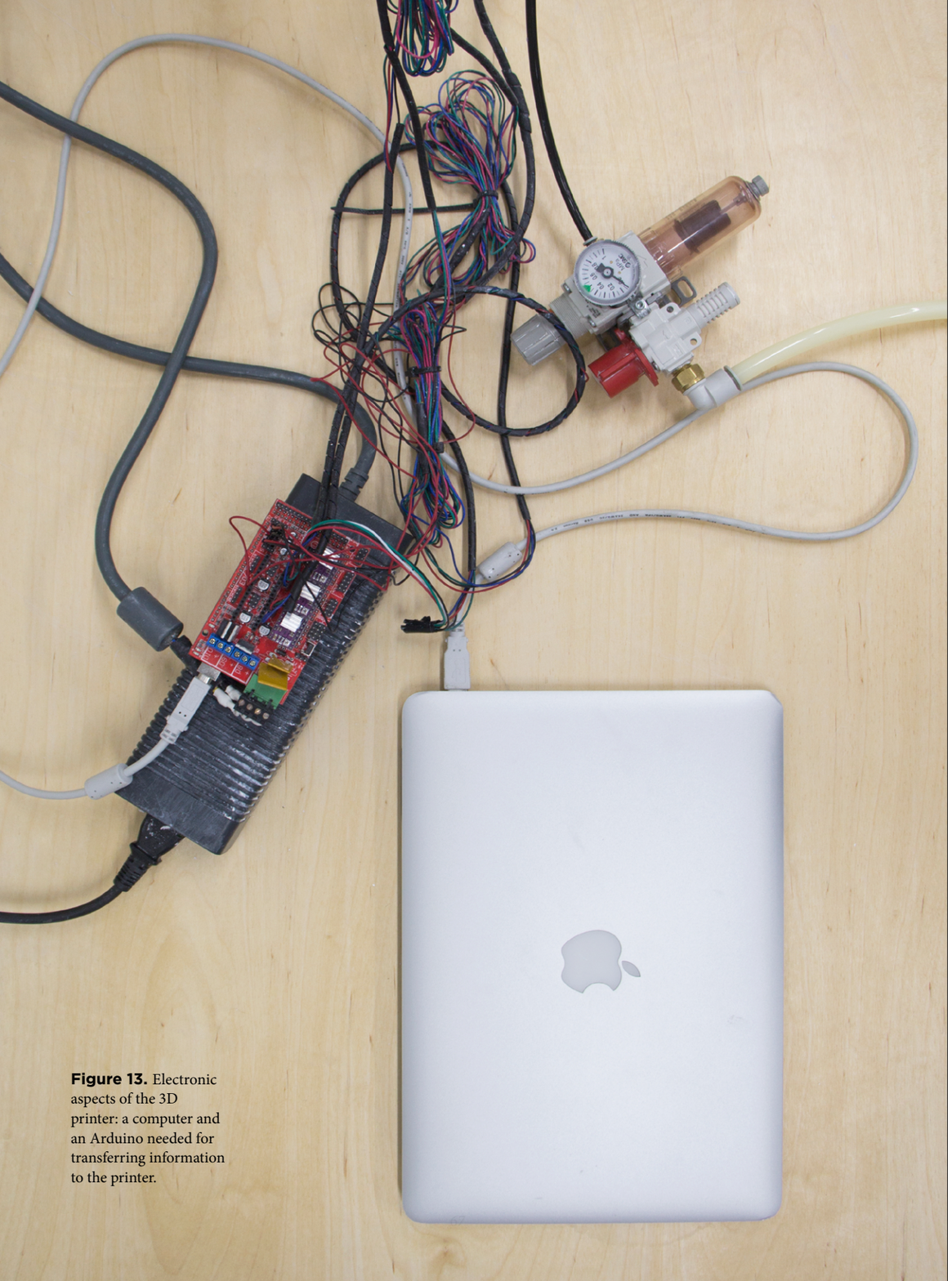

Figure 13. Electronic aspects of the 3D printer: a computer and an Arduino needed for transferring information to the printer.

5.2. *From Digital to Physical*

> **...3D printing employs an additive manufacturing process whereby products are built on a layer-by-layer basis, through a series of cross-sectional slices... All 3D printers also use 3D CAD software that measures thousands of cross-sections of each product to determine exactly how each layer is to be constructed... (Berman, 2012, p. 155) ...After printing, the object is treated similar as other objects formed from clay: bisque fire, glazing and then a second glaze fire... (Verbruggen, 2014, p. 174)**

The process begins in a 3D modeling software once the shape desired to print is formed. McCullough (1996) explains the 3D model as a workable construction in a digital medium. As designing a virtual shape, in a material-free space, one has to take into consideration the limitations that the printer requires such as sizes and thicknesses. (Bailey, 2016; Hansen and Falin, 2016).

The second step is to generate a G-code, a language that communicates information to a computerized tool on how the print will be constructed. G-code is the most popular open-source programming language that includes information such as the number of cross-sections, the coordinates, or the speed of the movement. (Bailey, 2016). In order to generate a G-code, a slicing software, *slicer* is required which converts the digital shape into layers of printable coordinates.

Throughout the process, I learned how to better communicate with the machine by understanding more of its digital and computational sides. For instance, while the G-code was initially a long script based on a stack of numbers for me, at the end of the process, I could modify it to fix problems or even intervene to the printing. When the software used to operate the printer continuously gave an error regarding the temperature—which was not relevant for a clay printer—and prevented it to start, I had to examine the G-code further. It became clear how each letter in the script such as G, E, F corresponded to a value such as motion, speed or temperature. Deleting or adding specific lines to the code was a way to communicate with the machine. I could not have fixed the temperature error without adding a line to the G-code. In addition to my hands-on skills, understanding the digital aspects made me feel more powerful in the process.

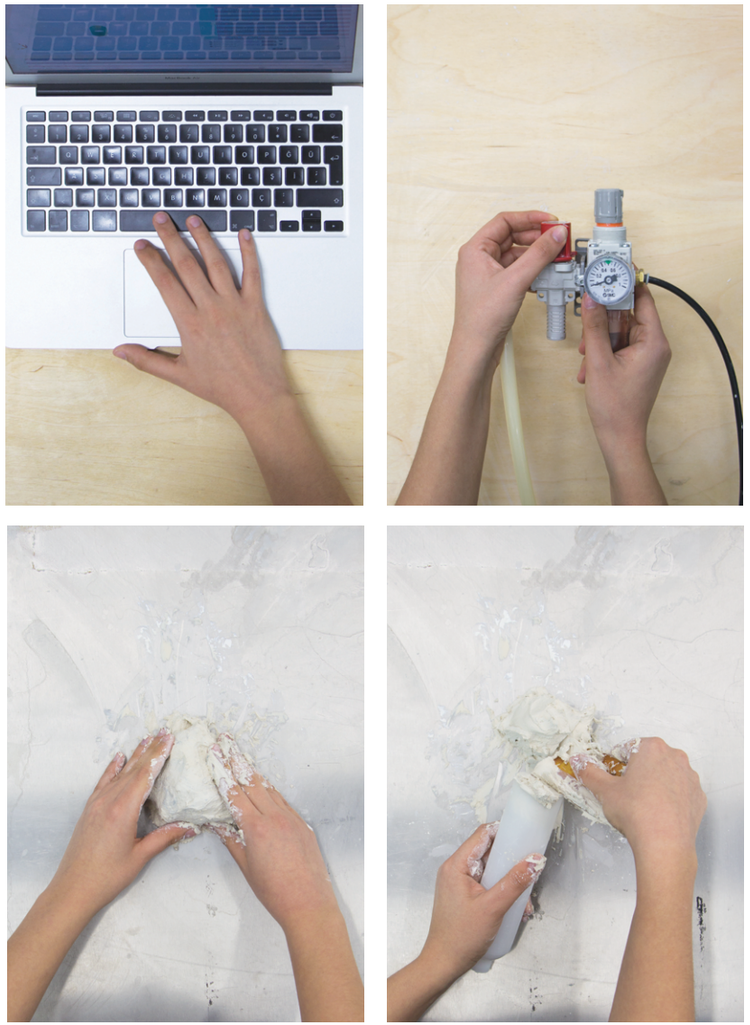

Figure 14. My hands switching between various digital and hands-on tasks within the process: 3D modeling, generating a G-code and operating the printer, arranging the air pressure, preparing the clay and filling the cartridge.

After the G-code is sent to the machine, printing begins and an object is built one layer by layer. In Verbruggen's point (2014), the action of printing connects the "digital, screen-based world" with the "physical, material world" (p. 174). Keep (n.d.) similarly states that "with code decisions are made at the numerical level and the visualization only comes after" in the physical world". He explains further that 3D printing enables him to "get the information out of the computer and made directly in clay, offering a physical object that can be held in the hand in a very short time span".

Of course, there is a difference between the digital and physical states; the 3D model constructed on the computer screen can look noticeably different when it is transformed into the physical world. Gravity and materiality that do not exist in the virtual state largely effects the outcome during this transfer. The shape appears to be different on account of nozzle thickness, pressure, speed, and material flow. Additionally, errors in coding may changes the transfer of digital to physical as well. For example, for a while in my process, the prints were forming smaller in size compared to the 3D model due to an error in the code. According to Keep (n.d.) another aspect of 3D printing that develops the outcomes differently in the physical world than in the computer is the layer lines—which creates a very strong visual character.

Within the process, the most material-based part was to prepare the clay before printing. There was always a very contrasting transition between the hands-on and digital when switching from clay making to printing. Most of the time, I enjoyed going back to the direct touch of the material after a while I spent with the printer. The clay recipe I used was consisting of porcelain (SSP), silica (FFQ) and feldspar (FFF). Preparing the clay was important and one of the most challenging part. The recipe requires strict calculation and precision, and preparing the clay in an inconsistent manner generates problems as I learned the hard way. The early frustrations I experienced with the printer was partly due to not having found the right clay ratio. If the clay is prepared too dry or liquid, there will be flaws during the printing—although, later on in my process, these flaws have become elements to experiment with. Verbruggen (2014) and Keep (n.d.) explain how the consistency of the material affects the plasticity of the object in the moment of printing. Clay, a soft and slow drying material, is quite challenging for building up an object that will not collapse under its own weight.

```
; external perimeters extrusion width = 2.00mm
(26.78mm^3/s)
; perimeters extrusion width = 2.00mm (26.78mm^3/s)
; infill extrusion width = 2.00mm (142.83mm^3/s)
; solid infill extrusion width = 2.00mm (35.71mm^3/s)
; top infill extrusion width = 2.00mm (26.78mm^3/s)

G28 ; home all axes
G1 Z5 F5000 ; lift nozzle
M302 P1; disable cold extrusion checking
; Filament gcode

G21 ; set units to millimeters
G90 ; use absolute coordinates
M82 ; use absolute distances for extrusion
G92 E0
G1 Z0.500 F7800.000
G1 X17.761 Y16.864 F7800.000
G1 F900
G1 X17.324 Y17.324 E0.16011
G1 X16.404 Y18.197 E0.48037
G1 X15.442 Y19.021 E0.80020
G1 X14.441 Y19.791 E1.11917
G1 X13.407 Y20.506 E1.43688
G1 X12.342 Y21.164 E1.75290
G1 X11.253 Y21.763 E2.06685
G1 X10.143 Y22.302 E2.37834
G1 X9.018 Y22.780 E2.68702
G1 X7.883 Y23.197 E2.99254
G1 X6.741 Y23.554 E3.29459
G1 X5.598 Y23.852 E3.59287
G1 X4.458 Y24.091 E3.88711
G1 X3.324 Y24.273 E4.17707
G1 X2.201 Y24.401 E4.46253
G1 X1.092 Y24.476 E4.74329
G1 X-0.000 Y24.500 E5.01917
G1 X-1.092 Y24.476 E5.29505
G1 X-2.201 Y24.401 E5.57582
G1 X-3.324 Y24.273 E5.86127
G1 X-4.458 Y24.091 E6.15123
G1 X-5.598 Y23.852 E6.44547
G1 X-6.741 Y23.554 E6.74376
G1 X-7.883 Y23.197 E7.04580
G1 X-9.018 Y22.780 E7.35133
G1 X-10.143 Y22.302 E7.66000
G1 X-11.253 Y21.763 E7.97150
G1 Z70.214 X12.342 Y-21.164 E4807.20208
G1 Z70.222 X13.407 Y-20.506 E4807.75815
G1 Z70.231 X14.441 Y-19.791 E4808.31717
G1 Z70.239 X15.442 Y-19.021 E4808.87843
G1 Z70.247 X16.404 Y-18.197 E4809.44119
G1 Z70.255 X17.324 Y-17.324 E4810.00470
G1 Z70.264 X18.197 Y-16.404 E4810.56822
G1 Z70.272 X19.021 Y-15.442 E4811.13098
G1 Z70.280 X19.791 Y-14.441 E4811.69224
G1 Z70.288 X20.506 Y-13.407 E4812.25126
G1 Z70.296 X21.164 Y-12.342 E4812.80732
G1 Z70.304 X21.763 Y-11.253 E4813.35974
G1 Z70.312 X22.302 Y-10.143 E4813.90784
G1 Z70.320 X22.780 Y-9.018 E4814.45098
G1 Z70.328 X23.197 Y-7.883 E4814.98857
G1 Z70.336 X23.554 Y-6.741 E4815.52005
G1 Z70.344 X23.852 Y-5.598 E4816.04489
G1 Z70.351 X24.091 Y-4.458 E4816.56263
G1 Z70.359 X24.273 Y-3.324 E4817.07283
G1 Z70.366 X24.401 Y-2.201 E4817.57512
G1 Z70.373 X24.476 Y-1.092 E4818.06915
G1 Z70.380 X24.500 Y0.000 E4818.55458
G1 Z70.387 X24.476 Y1.081 E4819.03509
G1 Z70.395 X24.402 Y2.190 E4819.52903
G1 Z70.402 X24.273 Y3.324 E4820.03631
G1 Z70.409 X24.091 Y4.458 E4820.54651
G1 Z70.417 X23.852 Y5.598 E4821.06425
G1 Z70.425 X23.554 Y6.741 E4821.58910
G1 Z70.432 X23.197 Y7.883 E4822.12057
G1 Z70.440 X22.784 Y9.007 E4822.65271
G1 Z70.448 X22.302 Y10.143 E4823.20130
G1 Z70.456 X21.763 Y11.253 E4823.74940
G1 Z70.464 X21.164 Y12.342 E4824.30181
G1 Z70.473 X20.506 Y13.407 E4824.85788
G1 Z70.481 X19.791 Y14.441 E4825.41690
G1 Z70.489 X19.021 Y15.442 E4825.97816
G1 Z70.497 X18.197 Y16.404 E4826.54092
G1 Z70.500 X17.885 Y16.734 E4826.74271
G92 E0
; Filament-specific end gcode
;END gcode for filament

M104 S0 ; turn off temperature
G28 X0  ; home X axis
M84     ; disable motors
; filament used = 4826.7mm (8.5cm3)
```

Figure 15. An extract from the G-code script used in the process, including information such as motion and speed.

5.3. *Partnership*

> **...Digital technologies should not be looked at as objects, or end points of human action, but as actors in constant communication with each other: non-human and human... (Dufva, 2018, p. 28)**

While I was working with a digital machine, I had to recognize that it had "an agency of its own and may act on its own terms" (Mäkelä & Löytönen, 2017, p. 242). I needed to accept its character and its input to the process. Due to this, I started to acknowledge the 3D printer, not as a production tool, rather as my partner in the design process, a partner who influences the outcome and who I improvise along. Right after I accepted our partnership, my previous frustration about the process has ended.

As Sennett (2008) suggests "reformatting… can inaugurate a leap of imagination, allow people to dwell, and productively dwell, in frustration" (p. 220). When I reformatted my approach towards the machine, the process instantly became more productive. McCullough (1996) similarly points out that using familiar arrangements can become a means of accessing unfamiliar, abstract digital states. When I accepted the machine as my partner, I have humanized it—which made it familiar. In this way, machine and I came on more equal ground. We did not have superiority over each other, rather we completed deficiencies of one another. The 3D printer had the digital and mechanical skills that I did not have, likewise, I had the intuitive and material-based skills that it did not have. Together, based on our synthesis, we were able to produce novel ideas. Likewise, it was neither the fault of the printer nor mine when the outcome failed.

Designer Daniel de Bruin (2015), through his project This New Technology, discusses the lack of authorship in the production process when using digital fabrication tools. Often times, people end up watching the machine without much physical activity as they wait to get their finished outcome out of the machine. My process with the 3D printer was quite the opposite; I was constantly active as the machine was working and we certainly shared the authorship of the outcomes. Some days, I had more influence on the machine and other days machine had more influence on me.

This partnership was only possible through the communication I was able to form. It was highly influenced by being able to understand the computational sides of the machine and the G-code language. Of course, it seems reasonable

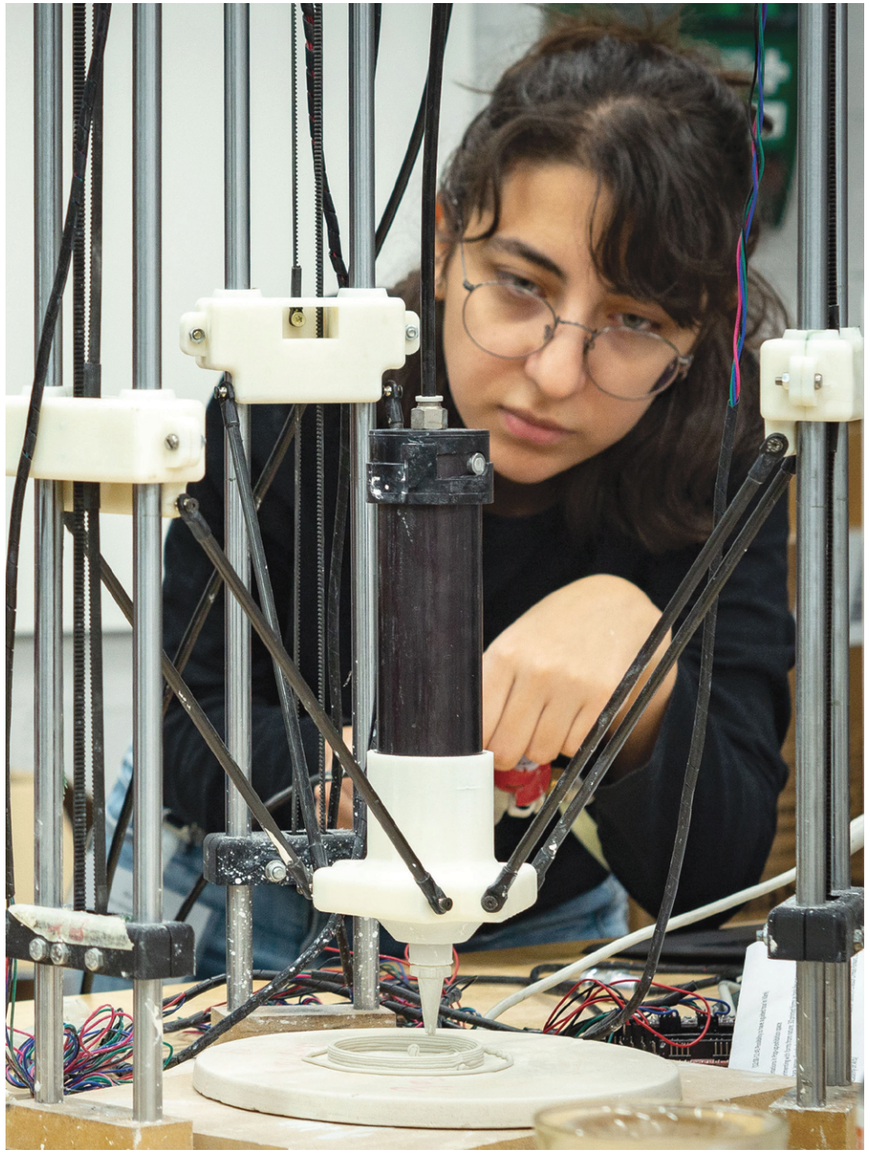

Figure 16.
Me working with the printer at the early stages of the process.
Photo by Minerva Juolahti.

Figure 17. Printing process of the first artifact. *Photo by Minerva Juolahti.*

that expecting the machine to produce for me without having a solid communication with it, the process will not go smoothly. This applies not only to digital production but to any other form of production. In fact, it reminds me of the times when I was getting help from the local craftsmen in Istanbul during the production phases of my bachelor's projects. In those situations, I was instinctively aware that I cannot ask the craftsmen to produce something for me right away. I knew that I had to build a communication first; I would chat with them separately from my project and even have tea with them. If my attitude would be wrong, they would not take me seriously. It was interesting to realize that there was a connection between my social interactions with craftsmen and my current communication with a digital machine. The process of working with both was not that different from each other.

The values I learned from improvisation were significant in order to form a partnership, to deal with the unforeseen process and to adapt to changing situations occurred by the machine's character. As we were working together with the machine, I tried to form a dialog by listening and responding. I did not

try to alter the step that the machine has taken but I aimed to take it forward. This approach was similar to the primary principle of improv theatre, the "yes, and…" principle which refers that each participant in the scene has to accept the offers from others. Participants have to be open to the possibilities arising over the course of performing together instead of judging or rejecting inputs of others (Robson et al., 2015; Sajnani, 2012). Performers in the improv theatre do not try to change the actions; instead of being stuck on an idea, they adapt and go with the flow. They always develop further and never backward. Such a manner suited my progress with the 3D printer since in an additive manufacturing process it does not make sense to try going backward. As artifacts are building forward, I also had to accept the inputs received from the printer.

Besides having a dialog with the machine, I was having a continuous self-dialog, attempting to find value in my practical process. In Fallman's (2008) terms, I was exercising design exploration. This approach 'often seeks to test ideas and to ask "What if?"—but also to provoke, criticize, and experiment to reveal alternatives to the expected and traditional' (p. 8). Likewise, in this process, the driving factor was to ask "What if?". I did not design the artifacts in advance, rather they began to take shape by following the inputs and wondering what could develop. For example, when a glitch occurred in the machine, my first reaction was to inquire: "What if I try to turn that glitch into an intentional element within the artifact?". Another prospect of working with a digital machine in this process, in fact, was my own amateurism. I was neither very knowledgeable in ceramics nor in 3D printing; I only had a base knowledge of both. As I was accepting the flaws of the machine, I also embraced my own amateurism. Therefore, my practical process became more open to try and fail. According to Schön (1983) in such a process:

> The practitioner allows himself to experience surprise, puzzlement, or confusion in a situation which he finds uncertain or unique. (p. 68) When a practitioner sees a new situation as some element of his repertoire, he gets a new way of seeing it and a new possibility for action in it. (p. 141)

5.4. *Errors, Glitches, and Mistakes*

Machines—especially the computerized ones—are expected to work flawlessly without any errors (Sennett, 2008). This may be true in the industrial scale, but with small-scale digital fabrication tools like the one I used, problems become an ordinary part of the process. In addition to the errors at the digital state, there were many glitches occurring due to the machine's DIY nature.

Nevertheless, the problems were not only caused by the machine but also based on the mistakes I made independently from the operation of the printer, such as preparing the clay batch in wrong consistency or misadjusting the settings in the slicer software.

Flaws occurring in the progress of creation can influence the outcome; it may add it a "character", thus may save it from being mechanical (Sawyer, 2000b). Accepting this fact in regards to a digital production process was relieving since I have been fearing that digitalization would cause a loss of character in the outcomes of design and craft practices. Errors, glitches, and mistakes enabled me to approach machine in a more hands-on manner. Throughout the printing process, I focused on exploring these flaws occurring—which does not exist in the digital state. However, it was not easy to reach this mentality. Identifying certain artifacts as "failed" was, in fact, one problematic aspect of progress in the beginnings—causing frustration and slowing down the process. As Boyle (2012) mentions "things are perceived as wrong when an expectation has not been met" (p. 5). Even if I have defined from the very beginning

Figure 18.
"Failed" artifacts or "a pile of noodles" as the workshop master Tomi Pelkonen refers.

that errors are valuable, as it seems, I still had expectations for the quality of artifacts. I started to question what made me define them as failed outcomes. Were they aesthetically not pleasing? Was I comparing the printed outcomes to conventional ceramic products? I believe my biased perspective was shaped by existing 3D printed ceramic pieces and the aesthetics that they have created. As I expected to get satisfactory outcomes, my satisfaction was defined by the common; this situation was something I have tried to escape by improvising.

As I mentioned earlier, the fact that something appears as a mistake is because of the norms of the practice. In the case of ceramics 3D printing, or in another form of "digital craft", this situation can be addressed slightly different. To exemplify, in traditional crafts, routines are defined and techniques are known, and having a defined routine already gives less chance for errors to occur. Since the clay printing is relatively a new and unknown practice, its routine is not yet formalized. When there are no definite rules for 3D printing, there cannot be any norms to violate; thus, the process could be more open to exploration.

There was a moment that I attempted to change my biased mentality and started embracing every outcome as a part of our communication with the machine, and as tools for my wider investigation. I was still encountering "pile of noodles", but I comprehended how to learn from them. Bertinetto (2013a) points out that artists or designer must be able to see and capture the significant potential of an event that seems destructive and "integrate it as an ingredient of his/her own artistic inspiration" (p. 124). Accepting that I cannot prevent errors and flaws from happening and that this was the nature of the tool I was using, I rather focused to make use of the errors. As I worked with the printer, in terms of Schön (1983), I reflected-in-action. Through this, I was finding meaning in uncertain and unique situations occurred and was reframing and integrating them as parts of the artifacts (Johns, 2009). In order to catch the mistakes, I had to be very "in" the process. Since there is no sensor indicating the errors, I had to be aware of all events and signs occurring at all times. This also required being flexible and adapting to situations as they arise. As Bertinetto (2013a) observes, catching and using the "unexpected accidents that are out of one's control" also requires the "ability to control the lack of control" (p. 130).

On each new day working with the printer there was a new problem —a potential input—in a different parameter: clay consistency, air pressure, code error… During my first interactions with the machine, I was spending longer times to understand what was wrong when an error occurred. When my communication with the machine has developed, it became easier to spot the problems and take them as inputs. For example, when I would notice the print was building up in a skewed way, I was not directly stopping the machine as I

did before. Instead, I was letting the machine continue printing and observing if this flaw could become an element to explore further. Moreover, there were several cases that I tried to achieve mistakes intentionally. I challenged the abilities of the machine as my partner to work in uncontrolled, unexpected or unwanted ways (Bertinetto, 2013a). Bertinetto communicates my motivation in this process very clearly:

> [Artists] sometimes produce conditions of uncontrollability and deliberately expose themselves to artistically… risky situations, in order to enhance the possibility of chance and surprise and to respond more inventively to the affordances of the medium… Sometimes they break their habits, deliberately modifying their usual tools and techniques so that they cannot work in an habitual controlled way… In other words: artists sometimes create the conditions for artistic luck, putting themselves in a situation in which their improvisational attitude is enhanced. (p. 129)

5.5. *Artifacts*

During this research, the activity of making acted as a tool for thinking; a way of knowing and understanding. The intendment in using 3D printing as a medium was not to explore possibilities of complex forms that digital technologies enable, or to introduce functional products. 3D printing and artifacts emerged served as tools for investigating my perception of digitalization. Thus, the artifacts represented in this thesis should not be accepted as the outcomes of this research. As a matter of fact, prints were not fired so that they could be recycled back as clay raw material. Not firing was a decision given not to attribute meaning to them as objects or products. The outcome of this thesis is the process itself.

All artifacts were based on the same 3D shape and G-code file: a hollow cylinder with a diameter of 50 millimeters. Choosing the shape as a cylinder was not really a thought-out decision but rather a quick one to limit the parameters of experimentation. While was the most basic geometric form both for ceramics and 3D printing, to me it also represented something digital; something mechanical, controlled and perfect. The reason for printing a hollow form was to give it no function or not to associate it with an object. Hollowness also provided the possibility of turning the artifacts upside down to find new meanings.

Artifacts in this thesis are the results of the continuous dialog between the product designer and a digital machine. Even though the digital part of each

artifact was utterly the same, they have differentiated because of the manual interferences, mistakes, and glitches. Achieving diversified shapes using the same G-code revealed how much probability could arise from the hands-on interaction with a digital tool—without even experimenting with the digital parameters. On the other hand, the process of printing also showed how this shape, a perfect circle in its digital state, could easily become misshaped in the physical state. Within my process, not the shape itself but detailing become important in the artifacts. Using a continuous and "perfect" form became a good base to represent how the signs and flaws from the printing process can be integrated into outcomes.

Each artifact was produced between 10 and 20 minutes depending on the parameters of material flow, nozzle size, and printing speed. When the start and end are determined—similarly to the process of an improvisation performance—one has to acknowledge that all the actions of production have to take place between this time span. Boyle (2012) states that such awareness for the amount of time available brings the process into more solid ground.

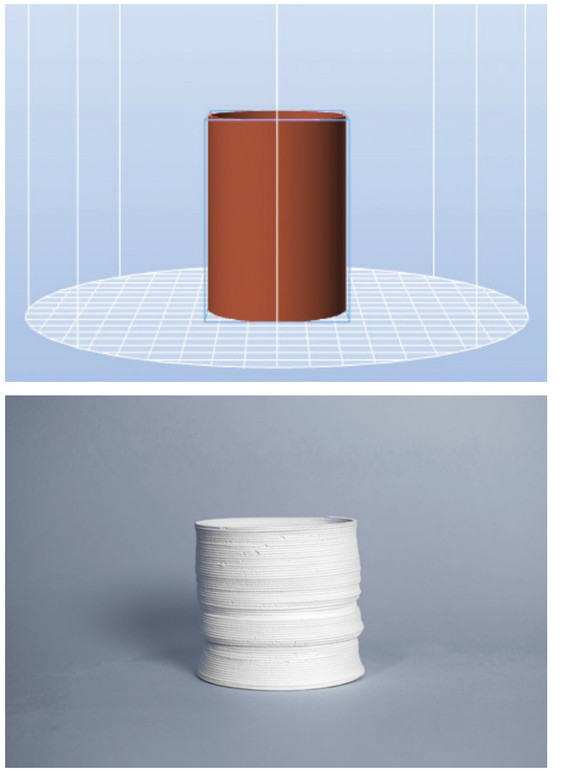

Figure 19.
Comparison of the print shape between a screenshot from the printing software and the physical artifact. Even though there is no intervene in the printing process, the printed shape is never realized as the "perfect" cylinder.

According to Sawyer (2000a), "unlimited options are available at the beginning of the scene" (p. 183). Through the dialog of the actors in the process certain paths open and close. Before starting to print an artifact, I did not know how it would turn out. When the printing began, I observed closely for the formation of unexpected signs. If I caught an input—a mistake, an error, a glitch—the idea of how to structure the artifact was defined. I adapted my actions according to the new goal I defined within the limited time frame. The repetition and transformation of the input formed the artifact. With time, the know-how of meaningful inputs and paths explored was formed, and this knowledge came in use in the future printing processes. Through combining and rearranging these explorations in various ways, new form and structure possibilities occurred. When in the beginning, I was improvising with the machine more freely, towards the ends of the process I introduced more of my control in and started to use the inputs in more structured ways. This also led me to investigate whether is it possible to repeat and compose the inputs, or are they just unique glitches that cannot be replicated.

At the end of the process, I analyzed each artifact and their place on the production storyline. Through this analysis, I collected them in different cases. This thesis presents 3 of these cases consisting of 27 selected artifacts. Each outcome within a case was not produced right after another but in a mixed sequence.

Figure 20.
Analyzing and grouping all artifacts at the end of the production process.

Figure 21.
A selection of artifacts exploring various inputs.

Case One: Pressure

Even if wanted to have a homogeneous batch of clay printing, the material partially starts to dry inside the cartridge. There is also usually entrapped air in the cartridge. Thus, in order to get smooth prints, it is needed to keep a constant eye on the printing process and accordingly adjust the level of pressure to reach the right flow of the clay. If more pressure is given, the clay flow increases and vice versa. In some situations, too much pressure may be applied unintentionally; this results with over-flowing of the clay that creates new structures and patterns. When this happened to me, I immediately took it as an input to push further and I found ways to control the effect both structurally and visually. Various patterns on artifacts can be achieved by increasing and decreasing the material flow and print speed. As a matter of fact, these pressure experiments were not always easy to repeat. I believe, it is highly dependent on the consistency of the clay. In some cases, when I tried to repeat a certain effect, it did not work out as before, yet new elements of patterns emerged.

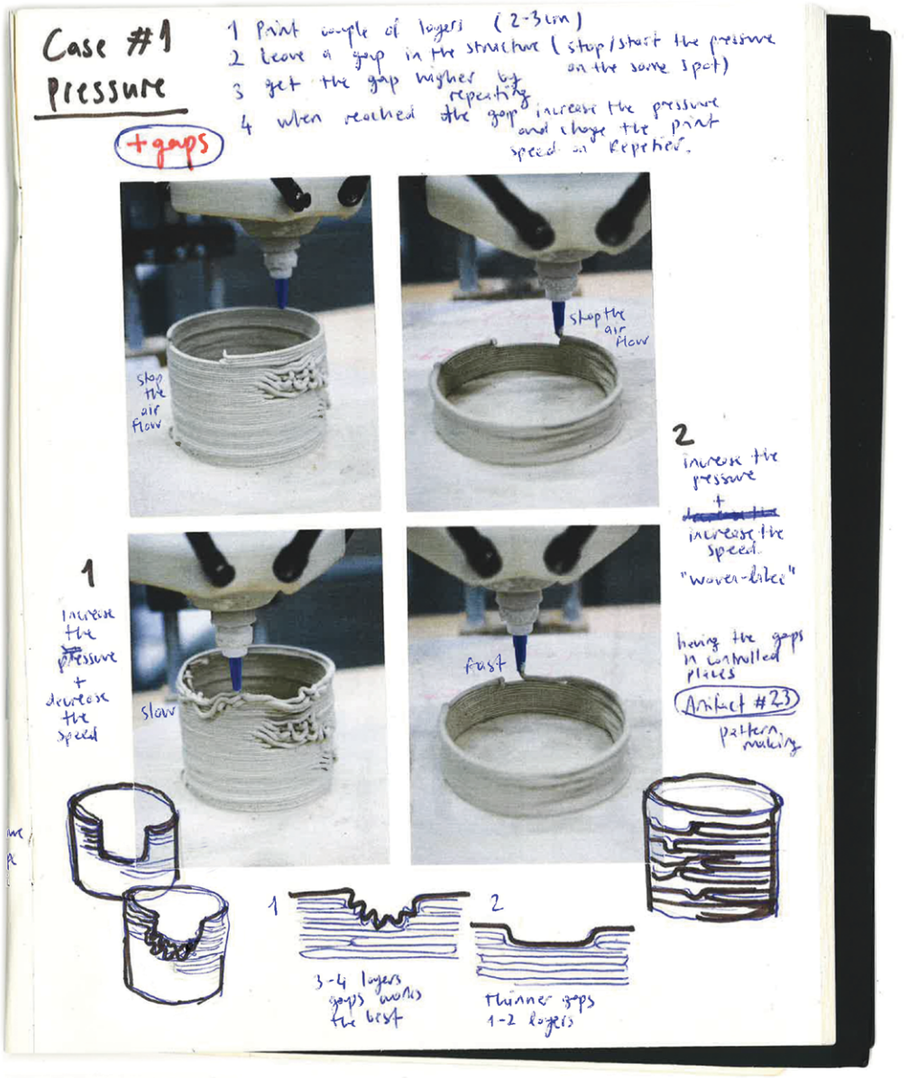

Figure 22.
Page from my logbook visualizing the production steps of the pressure case.

Part 5: Process

Figure 23.
A selection of artifacts
from the pressure case.

Artifact 1 *05.02.19*
Pressure control
explored as an input.

Artifact 2 *11.02.19*

Artifact 5 *14.02.19*
Sponge discovered as an input
when tried to fix a cracked
artifact and further trials on the
surface to embrace the visuality
of the pressure control.

Artifact 7 *16.02.19*
Structural problems
experienced when pressure
changed often.

Artifact 8 *16.02.19*
Trials on using pressure
and material flow.

Artifact 9 *16.02.19*

Artifact 13 *19.02.19*

Artifact 14 *19.02.19*
Input found in Artifact 13
controlled.

Artifact 17 *20.02.19*
An input to use for creating patterns explored.

Artifact 18 *20.02.19*
Input found in Artifact 17 controlled.

Artifact 22 *21.02.19*
Linear patterns achieved on the surface.

Artifact 23 *21.02.19*
Different patterns developed.

Figure 24. A closer look to Artifact 1 and Artifact 5 demonstrating different surfaces.

Figure 25. Detail from Artifact 18 revealing the input found for creating patterns while printing.

Figure 26. Different patterns developed in Artifact 23 and Artifact 18.

Case Two: Form

During the production of one artifact, due to a disconnection between the printer and my computer, printing stopped halfway through. I tried to adjust the settings in the software to get the printer starting from the exact coordinate where it stopped. What I imagined was that it would continue building on the same artifact which was still on the printing plate, yet this did not work. Instead, the printer started over from the zero points, pushed and widen the previous artifact and started a new one within the walls of the previous. At that time, the artifact on the printing plate was somewhat dry and structurally stable; therefore the print was not immediately destroyed by the push of the printing nozzle but rather deformed. This mistake resulted in a double-walled artifact. Later on, I took this as input and aimed to take it further to produce unconventional structures.

The second input came upon in the mentioned artifact was due to clay being finished in the middle of the printing. When there is no material left inside the cartridge, the air is blown onto the print and distorts a part of it. Under normal circumstances—if I do not want the print to be deformed—I needed to check the remaining material level oftentimes and stop the printer when the clay is about to run out. While some may believe that this situation destroys the artifact, I consider it as an element added to the form it. Within the process, I did not intentionally re-plan this situation to take place but when the times it occurred, I embraced it.

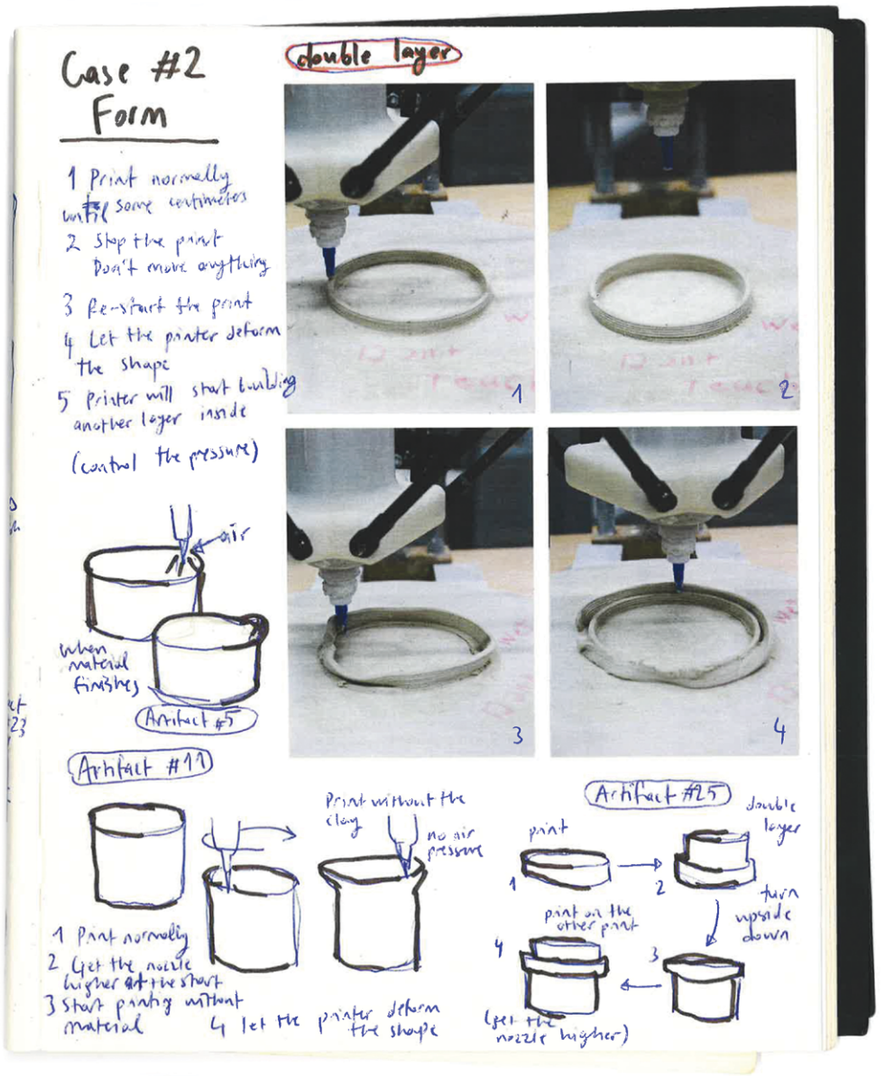

Figure 27. Page from my logbook visualizing the production steps of the form case.

Figure 28.
A selection of artifacts
from the form case.

Part 5: Process

Artifact 3 *11.02.19*
Two inputs explored in one artifact: double-walled structures and air blown to the print.

Artifact 4 *14.02.19*
Double-walled structure re-created.

Artifact 10 *18.02.19*
Another case of air blown into the print due to finished material in the cartridge.

Artifact 11 *18.02.19*
After an artifact completed, the nozzle moved upward, the printer restarted without any material flow and let to deform the shape.

Artifact 12 *18.02.19*
A collapsing part cut from the artifact and the remaining surface sponged to embrace the situation.

Artifact 24 *21.02.19*
The elements from pressure and form cases combined.

Artifact 25 *22.02.19*
Double-walled artifact created, turned upside down and re-printed on top.

Figure 29.
A closer look to Artifact
18 and Artifact 25.

Figure 30.
Detail from Artifact 3,
air blown into the print
due to finished material
in the cartridge.

Case Three: Texture

Many of the thin nozzles available at the workshop were broken, therefore I tried using one of the thick ones— in the diameter of 4 millimeters. Since a thick nozzle increases the material flow, the clay in the cartridge was finishing highly fast. In order to prevent this, I started to operate the machine at very low pressure. This affected the textures I get on the artifacts. Eventually, I learned how to control this as a visual element. I was also able to experience similar textures with thinner nozzles during my initial trials when the clay that I used was unintentionally dry.

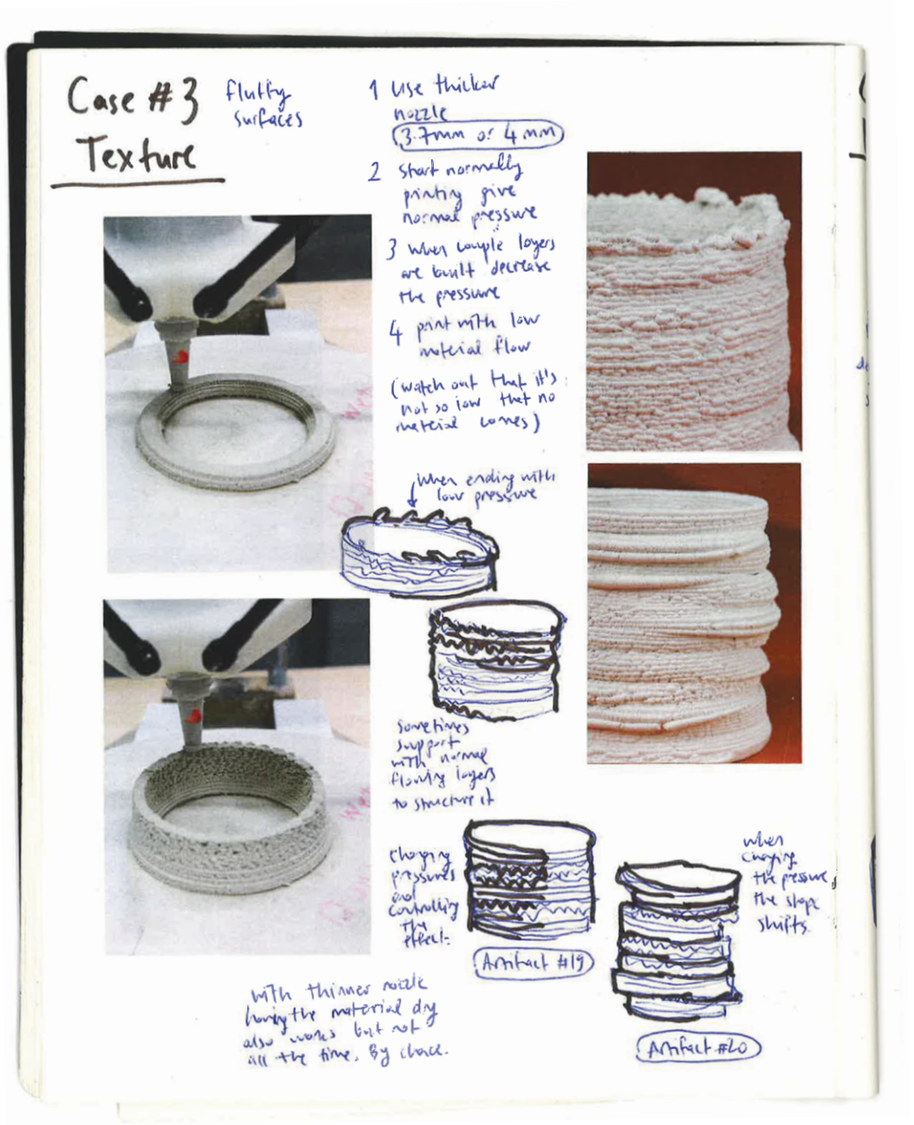

Figure 31.
Page from my logbook visualizing the production steps of the texture case.

Figure 32.
A selection of artifacts
from the texture case.

Part 5: Process

Artifact 6 *15.02.19*
Texture effect due to dry clay experienced.

Artifact 15 *19.02.19*
Texture effect experienced t he second time while using a thicker nozzle.

Artifact 16 *19.02.19*
Pressure is tested to see the difference on the surface.

Artifact 19 *21.02.19*
Textured and untextured parts of the artifact controlled.

Artifact 20 *21.02.19*
Textured and untextured parts controlled further and shifts on the shape noticed.

Artifact 21 *21.02.19*
Intentionally tried to generate shifts on the shape.

Artifact 26 *22.02.19*
Double-wall and texture elements combined using a thicker nozzle.

Artifact 27 *22.02.19*

Figure 33.
Detail from Artifact 19, textured and untextured surfaces combined.

Figure 34.
A closer look to Artifact 27.

Artifact 1 *05.02.19*

Artifact 2 *11.02.19*

Artifact 3 *11.02.19*

Artifact 4 *14.02.19*

Artifact 9 *16.02.19*

Artifact 10 *18.02.19*

Artifact 11 *18.02.19*

Artifact 12 *18.02.19*

Artifact 17 *20.02.19*

Artifact 18 *20.02.19*

Artifact 19 *21.02.19*

Artifact 20 *21.02.19*

Artifact 25 *22.02.19*

Artifact 26 *22.02.19*

Artifact 27 *22.02.19*

Artifact 5 *14.02.19*

Artifact 6 *15.02.19*

Artifact 7 *16.02.19*

Artifact 8 *16.02.19*

Artifact 13 *19.02.19*

Artifact 14 *19.02.19*

Artifact 15 *19.02.19*

Artifact 16 *19.02.19*

Artifact 21 *21.02.19*

Artifact 22 *21.02.19*

Artifact 23 *21.02.19*

Artifact 24 *21.02.19*

5.6. *Aftermath*

My aim in this process was not to explore the practical use of digital tools but to seek ways that designers can engage with them. Although my focus was not on the production of objects, I realized that most of the artifacts can actually be adapted to mass productional scale. When I understood more about the digital aspects of the printer, I became aware of the experiments—which I considered to be results of my humanly senses and interventions—could actually be coded and thus reproduced. In this case, producing with a computerized machine does not necessarily that perfect objects will emerge. Through the understanding of digital, we as designers can generate experimental, imperfect and nonidentical objects with the big-scale automated machines. Through the use of coding, objects can have a new meaning and character in digital production. Understanding that the digital process can be experimental was relieving since I was opposed to digitalization due to its monotonous processes which are not open to experimenting.

Even if I comprehended that an automated printer could possibly generate the same artifacts, this was only possible through using the small hands-on machine. If I started my investigation directly with the big printer—which is less accessible—I could have never gained the same perspective. I believe that the small printer basically can function as a prototyping tool to find ideas and to test ideas. Without experiencing hands-on how the digital machine works, I could not have imagined the same shapes, elements, thus could not have modeled or coded them. For example, even if I am now aware that pressure is an element that can be altered within the G-code, it would have been highly difficult to define this without having controlled the pressure in my hands with a physical gadget. As a matter of fact, because of starting my engagement with the DIY printer rather than the more professional one, my understanding of digitalization have developed in a salutary way. To some extent, being hands-on actually increased my interest in coding.

On the other hand, when looking at all artifacts after the whole process, I realized that the results looked considerably controlled. It seemed as I did not free my mind or took risks as much as I thought. Nevertheless, neither the process nor artifacts were never strictly planned or designed in advance. As the process always started in a spontaneous manner and an input to be followed was formed, I started to control the artifact within the time frame of printing. If the plan did not work, I was flexible enough to adapt to the changes. To recall, improvising is to find a balance between freedom and structure. Outcomes still looking structured at the end tells something about the way I work, and the designer I am. Controlling the prints were also partly due to structural reasons.

From the beginnings of the process, I have become aware that I could not be completely free in experimentation since the results collapsed during printing. Within the time span of this thesis, I used the same G-code for all artifacts to limit the parameters of experimentation. For the future processes, I am now able to push the boundaries of the digital more; I can explore complex shapes beyond the cylinder, and interfere in the code further.

Part 6:
Discussion

6.1. *Reflections and Conclusions*

> **While I was working with the 3D printer at the workshop, the mechatronics master Janne Ojala came by and we started having a chat. He was critical of my experiments and what was I trying to achieve. He asked me why was I using the small printer instead of the new "better" one. I answered him: "I can play more with the small one, the new printer just prints perfect things". He asked me back: "Why is perfect bad?" (Extract from logbook, February 19, 2019)**

"Why is perfect bad?" This question, in fact, touched on an important point in the investigation of my problematic relationship with digitalization. At that moment, I had no proper answer to this question. I did not know why I was against something being perfect, yet it being perfect was my initial negative reaction towards the digital. I have thought of this question throughout my process.

At the beginning of this thesis, the implication I had for digital presence rising in design processes was that there would be a loss in the sense of character and imperfection of the results. Instead, the results would become perfect and indistinguishable produced by a machine that replicates the same movements. As I have mentioned, what I feared was that digitalization would reduce experimentation and improvisation in design and crafts practices. Since a digitalized design practice requires structure, the process must be planned in advance; therefore there would be no room for mistakes nor exploration within production. However, at the end of the thesis, based upon my process with the 3D printer, I acknowledge that these perceptions of mine were not necessarily true.

Sennett (2008) describes that "only by understanding how something might be done perfectly, it is possible to sense [the] alternative, an object possessing specificity and character" (p. 104). He adds, through accepting the perfection of a machine, we can accept our own imperfection and "learn something positive about being human" (p. 81). Thus, technological changes in the field can teach us further about our own creative process and the value in the flaws we have. Through this understanding, the designer can aim for results that have character within a digital process and can produce imperfect objects using perfect machines. This was the way I made sense of something being "perfect" is not bad.

Although the value I see in working with materials with hands has not changed, I started to perceive that the idea of digital tools distance the designer from the material world does not have to be true (Hansen & Falin, 2016). As Duhva also mentions, "the division between… digital and physical is not [always] clear-cut" (p. 26). I realized that how digitalization can be approached is completely up to the designer. A digital tool can become very hands-on or very digital depending on how the designer is willing to work in this regard. The critical matter is deciding whether to fear the digital or to explore it. At the end of this thesis, my negative thoughts—or at least my prejudgments—began to disappear. I started to learn how to become open and at the same time critical, towards the changes happening in my field, instead of opposing to them without concrete arguments. One thing is clear to me at the end of this thesis and Peter Schaar (2016) puts this well in an interview:

> Fear is a poor basis for coping with change or the unknown—but naiveness will not help much either. The most important thing, in my opinion, is for people to come to grips with digitization and not pretend or believe that it is insignificant.

Fors (2010) refers to digitalization as "the beast" and suggests that focusing on the beauty of the beast can entail the possibility to investigate the ambiguous meanings of it. McCullough (1966), as well, explains that the level and quality of engagement with new mediums can be personal. One should find and delve into the element that drawing their interests during their encounters with the digital. In my case, being open towards digitalization became possible through accepting a 3D printer as my partner and improvise along with it. The element that drew my interest in the digital tool I chose to work with was its imperfection and the possibility that it created to maintain my connection with hands-on in its process. It can be said that I balanced the safe and uncomfortable zones to handle my investigation. I only explored a small part of the world of digitalization, but at least I have started.

Along the way, I realized that what bothered me with digitalization rising in my field was largely about the hype of using digital tools. Something I find problematic is the constant seek for new tools and techniques, and the notion that the use of new tools leads straightly to innovation. In my opinion, such an approach to digitalization cannot bring innovation and ones who are interested in digital fabrication should not see the new as glorious. The important thing is to learn how to be critical towards them; it should be questioned what is the use of these tools and what is the meaning in them. If the designer is aware of both the negative and the positive aspects of the tool they are using, digitalization can then be challenged to open up new possibilities and new ways of working.

Digital tools should not be accepted for the sake of their newness, but should also not be neglected. If we isolate ourselves from such changes in the field and stay within our traditional practice, we cannot have an impact on the transformation of the field. The statement I attempt to make is that if the changes in society and the professional scene pushes us to work in digital ways, we could find approaches to incorporate our own ways of working into these processes. We could be the ones who bridge the hands-on and digital. Hoyer (2016) similarly questions:

> Instead of limiting ourselves to criticism of the existing facts, can [we] find the possibilities that they open? The real task is not to keep up with the transformation of the market and technology, but to believe in utopias and in our ability to make changes. (as cited in Mäkelä et al., 2016, p. 18)

Another aspect of this thesis was understanding further what improvisation meant for me. What I find deeply special about it is that, firstly, how it enables to reach a free and expeditious state through practice and structure. Secondly, how it teaches to utilize the existing skills and knowledge into new structures and outcomes. As Bertinetto (2011) and Sawyer (2011) both point out, analyzing improvisation practice from the perspective of performing arts fields enables one to appreciate artistic creativity in general. This was true for me. Acknowledging certain values under the word "improvisation" made it easier to understand how my own creativity works, as well as to become aware and utilize them as elements during my practical process. For instance, could be that I was already embracing mistakes but now I esteem this more. Improvisation practically worked as a guideline that provides me methods on how the creative process can be practiced in a more efficient and meaningful way. For this reason, exploration of the concept of improvisation in the thesis is not only limited to this research; those aspects I have gained an understanding are influential on me beyond my experiments with the 3D printer. It brings me the mentality and the inspiration to follow further in my future projects and research.

This thesis is written from my own point of view as an individual designer but it may apply to other young designers who question their position in the rapidly changing discipline of design. One important thing to keep in mind is the variability of the fragments in this thesis. Working with a 3D printer or improvising were not unalterable or integral aspects. The printer could have been replaced with other digital tools such as a robotic arm or a CAD loom. Another researcher could have explored their relationship to digitalization differently and could have found a separate way of handling the unknown apart from improvising. The fragments I present in this thesis worked well together for me as an individual. The main concern is to find that personal way to deal with the changing nature of design.

In my case, the do-it-yourself clay printer represented the best medium of investigation for the context I was in. The machine I worked with was certainly related to the current time and state of design. Presumably, 10 years from now the same printer will not even exist; the 3D printing technology will be utterly transformed into another state, and various contemporary digital machines will appear. This is why the fundamental matter in my research is the approach I have been exploring. This thesis highlights how valuable is to find an approach to deal with continually emerging unfamiliar tools and processes and be able to integrate your own way of working into them. Ultimately, when the practice of design and the future of work remain to change, the personal approach that the designer developed can still remain valid.

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This thesis arises from the effort of a young designer striving to position herself within the digitalization of the product design field. In this open-ended process where research, production, and personal experiences are intertwined, I enter into a self-dialog that enables me to question the ambiguous meaning of digitalization and my own standpoint. Through the process, I explore how to be open towards the digital and I discuss that the level and quality of approaching changes in design can be personal. The bridge I find between digitalization and improvisation enables me to find a means of working hands-on with a digital tool. This thesis highlights that developing a personal approach retaining the connection to the designer's own way of working is fundamental for dealing with the rising digital presence in design.

2019